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(54) Title: MULTIPATH PROPAGATION DELAY DETERMINING MEANS USING PERIODICALLY INSERTED PILOT SYMBOLS
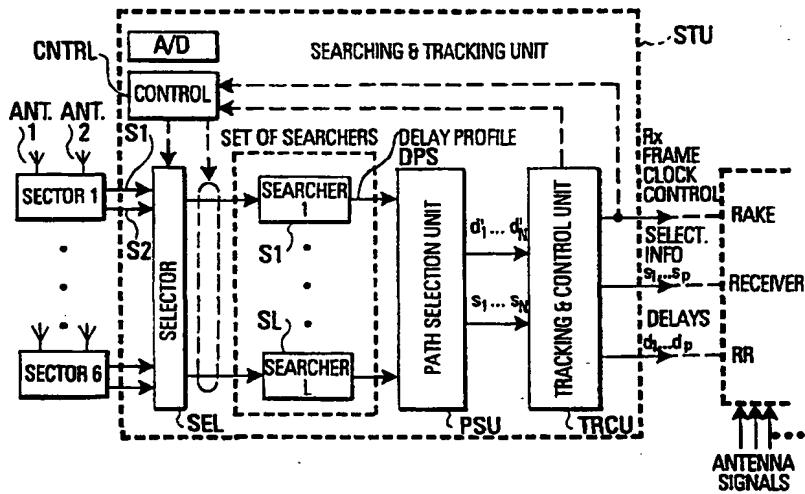
(57) Abstract

A multipath propagation delay determining means (STU) for determining a power delay spectrum (DPS) of a signal on a plurality of propagation paths within a cell of a CDMA communication system, comprising A/D conversion means for converting a CDMA multipath signal received from at least one antenna (Ant1, Ant2) into a signal (S1, S2) consisting of consecutive radio frames including consecutive time slots with complex pilot symbols and data symbols, demultiplexing means for extracting complex pilot symbols and data symbols from at least two consecutive time slots of each radio frame and for storing them consecutively in memory means; and a searching means (S1...SL) for determining a power delay profile (DPS) on the basis of said extracted and stored complex pilot symbols and said data symbols.

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MULTIPATH PROPAGATION DELAY DETERMINING MEANS USING
PERIODICALLY INSERTED PILOT SYMBOLS

10   **Field of the Invention**

The present invention relates to a multipath propagation
delay determining means, in particular for a CDMA base
station, in which pilot symbols contained periodically in
15   the signal radio frames are used for an efficient power
delay profile calculation and an improved path selection,
tracking and sector selection.

In particular, the invention relates to performing the
20   afore-mentioned functions in connection with a so-called
RAKE receiver.

Background of the Invention

25   Code-division multiple access (CDMA) based on direct-
sequence (DS) spread-spectrum (SS) techniques is a
prospective candidate for the third generation of wideband
cellular mobile telecommunication systems (e.g. in UMTS, as
IMT-2000 described in reference [1]: J. E. Padgett et al:
30   "Overview of Wireless Personal Communications", IEEE
Communications Magazine, January 1995, pages 28 - 41).

As shown in Figure 1 an area, where several mobiles
stations MS1, MS2 ... MS are served by a (fixed) base
35   station BS, can be regarded as a cell of the CDMA
communication system. It has already been demonstrated that
the DS-SS CDMA technique is capable of transmitting data
signals of high transmission speed, for example within RACE

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CODIT project (reference [2]: A. Baier et al: "Design Study
for the CDMA-based Third Generation Mobile Radio System",
IEEE Journal on Selected Areas and Communications Vol. 12,
May 1994, pages 733 - 743). The potential advantages of the
DS-SS CDMA technique have also been tested in the Ericsson
Wideband-Testbed (WBTB) project. DS-SS-CDMA has already
been used in commercial systems like systems based on IS'95
(D.P. Whipple: "The CDMA Standard", Applied Microwave &
Wireless, December 1994, pages 24 - 37). Also in Japan a
great importance has been attributed to the DS-SS-CDMA
system.

Whilst some basic properties of the CDMA receiver and the
CDMA telecommunication system are implicit due to the CDMA
method, special realizations of the despreaders, the
searchers and path selection units have not been
investigated in a great detail up to now, since a standard
for the W-CDMA has so far not been established. Therefore,
the present invention relates to special realizations of
the individual units necessary in the CDMA-receiver. Since
the inventive CDMA base station, the CDMA reception method
and the CDMA system are intrinsically based on the DS-SS
CDMA technique, hereinafter the basic technique of DS-SS
CDMA transmission will be considered (see also the basic
reference [4]: A.J. Viterbi: "CDMA: Principles of Spread
Spectrum Communication, Reading, MA: Adison-Wesley, 1995").

DE 19506117 C1 describes a method for estimating the
impulse response of a transmission channel, over which
CDMA-method-coded information is transmitted. The
information is spread on the transmitter side with a
spreading code and is despreaded on the receiver side with
a corresponding corelation code. The temporal changes of

5   the propagation paths are taken into account on the
     receiving side.

     DE 19615257 A1 describes a CDMA-RAKE-receiver including a
     sub-chip-resolution. This receiver is adapted for use in a
10   DS-CDMA-communication system. It includes a channel
     estimation means which can resolve multipath-components,
     which are closer than a single chip-interval.

     Basic CDMA-Technique

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     Basically, in the CDMA technique, an input signal I having
     a limited bandwidth (transmission speed) is spread with a
     predetermined spreading sequence (PN sequence) of a much
     higher bandwidth and thus an output signal O is produced
20   having a much higher bandwidth than the input signal I as
     is shown in Figure 2a. Since all signals considered in the
     CDMA technique are digital signals, the expression
     "bandwidth" really means the chip rate.

25   As is shown in Figure 2b, two bits of a digital signal
     constitute one symbol in a CDMA method using a QPSK
     modulation. Each bit of the symbol will be spread with a PN
     sequence, and the spread signal (the bottom curve in Figure
     2b) consists of a plurality of "chips", whereby a chip is
30   defined as a 0→1 and 1→0 (or 1→0 and 0→1) portion of the
     despread signal.

     As indicated in Figure 2a, a so-called spreading gain M
     equal to the ratio of the chip rate to the symbol rate is
35   defined. M basically describes the spreading factor, i.e.
     how much wider the bandwidth has become due to the
     spreading with the PN sequence. Of course, since all

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5   signals are digital also the PN sequence is a signal which
    is digital (consisting of a number of bits).

    If the original signal I has to be recovered in the CDMA
    receiver, of course a despreading process has to be carried
10 out in a despreader DSP as shown in Figure 2a, wherein the
    original information is obtained by multiplying the spread
    signal (sequence O) with the original PN sequence that was
    used for the spreading process.

15 However, as shown in Figure 3, all information in the CDMA
    channels are transmitted clockwise, i.e. in terms of
    successive radio frames RFn. This means, that the spreading
    and despreading must be performed also framewise. In the
    transmitter, each frame is spread with the spreading
20 sequence (PN sequence) starting with the beginning of the
    frame and of course this means that also in the receiver
    there must be a time synchronized (i.e. time-aligned)
    despreading, i.e. the despreading sequence must be aligned
    to the beginning of the received frame. The PN sequence is
25 of course a sequence which is known to the transmitter and
    receiver, but the time-alignment for the block-wise (M)
    integration (despreading) must be performed in the
    receiver.

30 A principle overview of a base station receiver is shown in
    Figure 4. As is seen in Figure 4, the demodulator DEMOD
    receives inputs from the PN generator PN-GEN (generating
    the PN despreading sequence) and from a timing control unit
    TCU. In principle, signals from various antennas Ant0, Ant1
35 from various sectors 1 ... 6 are input to an automatic gain
    control circuit AGC and the samples are input to a so-
    called searcher S (the function of which will be explained
    below) which calculates the (power) delay profiles. The

5   demodulator DEMOD (comprising a so-called RAKE receiver to
    be explained below in more detail) outputs the demodulated
    and despread bit sequence to the decoder DEC. As will be
    seen below, the searcher S actually comprises a searching
    and tracking unit provided for input signals from all
10 sectors (parts of a cell as shown in Fig. 1, 12). The
    output from the searcher S are the delay values and the
    (sector) selection information.

    The reason why the searcher S also comprises a tracking
15 unit results from the problem of multipath propagation
    which is an intrinsic property of any mobile communication
    system. Therefore, hereinafter the multipath propagation in
    connection with the tracking features of the CDMA system
    are explained.
20

    CDMA Multipath Propagation

    As shown in Figure 5, between a mobile station MS and a
    base station BS there is not only the direct path P1 but
25 also indirect paths P2, P3, for example due to reflections
    at buildings H, cars C or mountains M. This mixture of
    direct and indirect paths (i.e. multipath propagation)
    means that the received signal energy (i.e. the power per
    sample of the transmitted sequence) does not have a
30 constant time delay (corresponding to the velocity of
    light). This means, that a sample (bit) transmitted at t_0
    arrives at the base station BS at the time t_1 and another
    portion of the energy arrives at the base station BS at
    time t_2 due to a further propagation of the energy along an
35 indirect path P2 or P3. This leads to the delay profile per
    sample as is illustrated in Figure 5. That is, each sample
    is spread over the delay profile, often characterized by

5   (fading) single paths. Thus, in Fig. 5 the time differences
     t_1-t_0, t_2-t_0 etc. are defined as delays d_1, d_2 etc.

     In conventional DS-SS-CDMA techniques the problem of
     multipath propagation is usually handled by the so-called
10   RAKE receiver as is described in the afore mentioned
     references [2] and [3]. The basis of the RAKE receiver is
     basically to collect the energy per symbol not only from
     the direct path P1 but also from the plurality of indirect
     paths P2, P3. Essentially the RAKE receiver allocates a
15   "marker" (in CDMA such markers are called "fingers") to the
     strongest single paths (i.e. to the maxima) in the delay
     profile of the corresponding signal. Thereafter, the
     collected energy or the information of each path is
     individually demodulated/detected per path (i.e. per RAKE
20   finger). Thereafter the information after demodulation is
     combined, e.g., with a maximum-ratio-technique.

     If the mobile station MS with respect to the base station
     BS was stationary, then of course the delay profile with
25   respect to also stationary reflection objects H, M could be
     pre-estimated and calculated. However, one of the intrinsic
     properties of a mobile radio communication network is the
     "dynamic" variation of the delay profile when the mobile
     station MS or one of the non-stationary objects C move.
30   Therefore, also the delay profile exhibits a dynamic
     characteristic. Thus, the resource allocation and the time
     synchronization of the RAKE receiver has to be performed by
     continuously estimating and evaluating the delay profile.

35   In the CDMA technique a so-called searching and tracking
     unit is normally used to identify the paths within a delay
     profile.

5   **Searching and Tracking Unit**

A major task of the searching and tracking unit is to
identify the paths within a delay profile and keep track of
changing propagation conditions, e.g. as a consequence of
10 distance variations between the mobile station MS and the
base station BS. Since in the base station receiver the
despreading sequence must be fully time-aligned to the
sample (energy) arriving at the base station BS along a
plurality of paths, it is essential that the searching and
15 tracking unit knows the relative delays d_1, d_2, ... d_p of
the paths within the delay profile. If so, the requested
time-synchronization for each RAKE finger can be
maintained. Therefore, the searching and tracking unit must
on the one hand estimate the delay profile and on the other
20 hand must assign the RAKE fingers accordingly in order to
time-align the PN despreading sequence to the exact arrival
time of the partial sample energy arriving over each
individual path.

25 Often a certain frame structure with fixed alignment of
information signal (frames) and spreading sequences is
applied and therefore the time-synchronization can be split
up into a frame-synchronization and chip-synchronization.
As a consequence of fading and changing propagation
30 conditions the estimation of the delay profile carried out
by the searching unit has to be updated according to the
specific needs of the mobile radio channel.

Therefore, the searcher has to fulfill two contradictory
35 requirements, namely, on the one hand it must minimize the
time needed for updating or calculating the exact delay
profile and on the other hand it must provide a
sufficiently fine time resolution for time-aligning the PN

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5   despreading sequence to the beginning of the respective
     frame or symbol, i.e. to minimize the self-noise of the PN
     sequence.

Conventional Searching and Tracking Unit

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     Prior art searcher algorithms and implementations in
     communication applications mainly relate to IS-95
     (commercial) systems, either for the up-link (MS → BS) as
     described in reference [4] and reference [5]: K. Easton and

15   J. Levin: "Multipath Search Processor for a spread Spectrum
     Multiple Axis Communication System", WO 96/10873, April 11,
     1996" or for the down-Link (BS → MS) in reference [6]: R.
     Blakeney et al "Demodulation Element Assignment in a System
     Capable of Receiving Multiple Signals, WO 95/12262, May 4,

20   1996".

     As already shown in Figure 3, each superframe SRF consists
     of a number of radio frames RFn which each consist of a
     number of time slots TSm. Each time slot TSm has a number

25   of pilot symbols PS2 which allow to detect the beginning of
     the time slot TSm. Therefore, the pilot symbols can be used
     in order to achieve the time-aligning of the PN despreading
     sequence to the beginning of the individual time slots.

30   In order to achieve a high system capacity, the prior art
     according to the IS-95 systems do not use pilot symbols in
     the up-link channel. If the pilot symbols are not
     contained, the searchers must examine all possible signal
     variations which random data can produce and perform the

35   delay profile calculation on the basis of such an
     estimation. In the down-link channel for example in the
     Ericsson WBTB system a continuous pilot signal is inserted.

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5   The up-link delay estimation is based on a decision
    feedback.

Prior Art Searching and Tracking Unit

10 As described in WO 96/10873 a typical receiver uses
    multiple searcher elements working in parallel to provide a
    fast searching process. Such a searching and tracking unit
    comprising a plurality of searchers S is shown in Figure 6.
    As shown in Figure 6, a plurality of searchers S1 ... SL
15 work in parallel as a consquence of the multiple signal
    sources (antennas from each of the sectors 1 ... 6) which
    should be examined. The parallel operation is also a
    consequence of the "real time" requirements. Namely, if a
    real-time serial search is applied, for each new time
20 offset, (code phase imcrement since in the CDMA method each
    channel is identified by a respective time offset to a
    synchronization pulse) an additional correlation (dwell)
    time must be spent.

25 To avoid this "real-time slavery", WO 96/10873 suggests a
    new hardware architecture for the searcher. The essence of
    the new searcher architecture is to de-couple the operation
    of the correlator (based on a Fast Hadamard Transform-FHT
    processor) from the real time requirements by introducing a
30 buffer for the input signal samples and a PN sequence
    buffer for the desprading sequences. In this way the FHT
    processor can run at much higher speed evaluating quickly
    the large number of time offsets with respect to the
    reference (synchronization) signal. In WO 96/10873 an
35 efficient technique for supplying high speed data streams
    to the FHT processor is included. The hardware
    architechture is similar to the one implemented within
    CODIT and the WBTB test project of Ericsson. The WBTB

5   approach can further be described as a combination of
     coherent accumulations with non-coherent averages in order
     to reduce the variance of estimates.

     Path Selection Unit

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     As is also shown in Figure 6 for the conventional system
     (see for example WO-96/10873) in addition to the parallel
     working searchers S1 ... SL there is a path selection unit
     PSU that selects the individual paths from the calculated
15   power delay profiles as determined by the set of searchers.
     As is seen in Figure 5, the delay profile has a number of
     peaks and the path selection is conventionally done by
     scanning the calculated delay profile for a certain number
     of strongest peaks, whereafter these peaks are compared to
20   a threshold, which is derived by multiplying the "noise
     floor" of the delay profile with a constant value.

     The disadvantage with such a kind of path selection is that
     it is not very accurate, in particular when cells are used,
25   which are subdivided into sectors, and when multiple
     antennas per sector (antenna diversity) is used.

     Summary of the Invention

30   As described with reference to Figure 3 above, each time
     slot comprises a number of pilot symbols and over the
     successive time slots it may be said, that the pilot
     symbols are periodically inserted (after each 0.625 ms).
     Each logical channel (information) corresponds to one voice
35   or packet data channel. In a commercially interesting
     system up to 300 voice channels per base station must be
     handled simultaneously. This means, that each voice or
     packet data channel has to simultaneously undergo the delay

5   profile estimation and the updating of the delay profile
     simultaneously for which the PN despreading sequence must
     be appropriately time-aligned to the beginning of the
     respective time slot.

10   The above described solution of estimating the absolute
     delays is not optimal for the CDMA systems with
     periodically inserting pilot symbols. On the other hand,
     another solution suggested in the Ericsson WBTB project
     proposes that a long buffer is used that is able to reflect
15   all possible delay values within a cell. The hardware in
     such a system is extremely complex when 300 voice channels
     per base station need to be handled, since essentially 300
     parallel working searchers must be provided.

20   **Object of the Invention**

     Therefore, a first aim of the invention is to provide a
     multipath propagation delay determining means, in
     particular for the DS-SS-CDMA base station receiver where
25   no complex hardware is necessary for the searchers, whilst
     still an accurate estimation of the power delay profile for
     a high number of voice channels can be achieved in real
     time.

30   As also described above, one of the most important general
     problems is to select the individual paths from the delay
     profile, since the estimation of the delay values is
     necessary in order to solve the problem of the multipath
     propagation. In the conventional path selection unit a
35   threshold is set for the discrimination between the signal
     and the noise. Furthermore, reference [7]: E. S. Sousa, V.
     M. Jovonvich and C. Daigneault, "Delay Spread Measurements
     for the Digital Cellular Channel in Toronto", IEEE

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5   Transactions on Vehicular Technology, Vol. 43,. No. 4,
     pages 837 - 847, November 1994" contains a description of a
     modified threshold setting method for the channel delay
     profile estimation using a so-called constant false alarm
     rate technique (CFAR). However, this method is extremely
10   complex and is more suitable for off-line signal processing
     and does not fulfill the requirements of the real-time
     implementation in a commercially interesting CDMA
     telecommunication system.

15   Therefore, another aim of the invention is to provide a
     multipath propagation delay determining means, in
     particular for a DS-SS-CDMA base station receiver, in which
     an accurate path selection estimation in a real-time
     application can be performed.
20
     Furthermore, as described above, in the CDMA system cells
     may be subdivided into sectors and multiple antennas may be
     used per sector (antenna diversity). Thus, the accuracy of
     the delay profile estimation and the treatment of the
25   softer (i.e. sector-wise) handover has to be specified and
     optimized with respect to the special requirements of a
     hardware with as low complexity as possible.

     Therefore, a further object of the invention is to provide
30   a multipath propagation delay determining means, in
     particular for a DS-SS-base station receiver, allowing an
     accurate delay profile estimation and a softer handover
     when cells are subdivided into sectors in which an antenna
     diversity is used.
35
     The above aims can be summarized in a single object of the
     invention, i.e. to provide multipath propagation delay
     determining means, in particular for a DS-SS-CDMA-base

5   station receiver, in which a great number of voice or
     packet data channels with periodically inserted pilots
     symbols can undergo in real-time simultaneously an accurate
     despreading, an accurate delay profile estimation as well
     as an accurate path selection and location determination.
10

Solution of the Object

     The above object is solved by a multipath propagation delay
     determining means, in particular for CDMA base station
15   receiver according to claim 1, 24, 26.

     Essentially, as a primary aspect of the invention an
     improved power delay profile is calculated according to the
     invention by averaging delay profiles estimated over a
20   plurality of successive time slots and frames. Further
     aspects of the invention are claimed in the dependent
     claims.

     One preferred aspect of the invention is how the delay
25   profile is searched for local maxima corresponding to the
     individual paths. Here, the peaks in the profile are
     removed or equivalently set to 0 to obtain a noise floor.
     This noise floor is averaged to result into a single value.
     Then a threshold factor is multiplied with this noise floor
30   level. Then the original unmodulated delay profile is
     compared with the multiplied value and those maxima are
     selected as useful paths which lie above the multiplied
     value threshold.

35   Another aspect of the invention is the usage of an antenna
     diversity, i.e. two antennas in each cell or sector each
     providing a delay profile. Here the two delay profiles from
     each antenna are added and only such peaks are selected in

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5   this added profile which lie above the multiplied threshold
     value. Then the two delay profiles are compared separately
     with the multiplied threshold detected for the combined
     delay profile and only such paths are selected for a single
     antenna signal that also lie above the threshold within the
10   respective single delay profile. The correlated evaluation
     of the delay profile for the path selection based on two
     delay profiles simultaneously is completely different to an
     individual consideration of the delay profiles of each
     antenna.
15

     According to another aspect of the invention each cell is
     divided into several sectors each served by two antennas
     using antenna diversity. Whilst in the prior art an
     information must be transferred to the base station as to
20   which sector contains the mobile station, an aspect of the
     invention uses a "dynamic searching of the sectors"
     combined with individual path selections and a highly
     accurate softer hand-over. A "location" determination of
     the mobile station MS can be performed based thereon.
25

     Further advantageous embodiments and improvements of the
     invention may be taken from the dependent claims.
     Hereinafter, the invention will be described with reference
     to its embodiments in combination with the attached
30   drawings.

     Brief Description of the Drawings

     In the drawings:
35

     Fig. 1   shows the typical arrangement of CDMA cells and
                 mobile stations MS and base stations BS according
                 to the prior art;

Fig. 2a   shows the principle idea of the DS-SS CDMA
            spreading and despreading using a PN sequence;

Fig. 2b   shows the definition of symbol, bit and chip in a
            CDMA method using QPSK;

Fig. 3   shows channel formats with periodically inserted
            pilot symbols in a CDMA transmission channel;

Fig. 4   shows a block diagram of a conventional base
            station receiver;

Fig. 5   shows a delay profile DPS and the problems of
            multipath propagation;

Fig. 6   shows the block diagram of a searching and
            tracking unit STU used in the invention;

Fig. 7   shows an embodiment of the selector SEL and the
            searcher S1 shown as part of the searching and
            tracking unit STU in Fig. 6, according to the
            invention;

Fig. 8   shows an embodiment of the pilot demultiplexer
            PI-DEMUX shown in Fig. 7, according to the
            invention;

Fig. 9   shows an embodiment of the despreader DESP and an
            embodiment of the coherent accumulation/averaging
            means ACC-AV of the selector S1 shown in Fig. 7,
            according to the invention;

5   Fig. 10   shows an embodiment of the path selection unit
                PSU for the example of selecting the paths from
                two antennas in sector 1, according to the
                invention;

10   Fig. 11   shows the usage of pilot symbols and frames and
                the used time period for performing a coherent
                averaging in the coherent accumulation/averaging
                means ACC-AV shown in Figs. 7, 9, according to
                the invention;

15

     Fig. 12   shows the subdivision of a cell into individual
                sectors, each serviced by two antennas Ant1,
                Ant2;

20   Fig. 13   shows a diagram how sectors of a cell are
                dynamically searched according to a search method
                of the invention;

     Fig. 14   shows an embodiment of the path selection method
25   according to the invention;

     Fig. 15   shows an embodiment of the searching and tracking
                unit including 2 searchers S1, S2 for searching 6
                sectors including an antenna diversity;

30

     Fig. 16   shows non-detection and false alarm probabilities
                for the case of 3 sectors;

     Fig. 17   shows non-detection and false alarm probabilities
35   for the case of 1 sector;

     Fig. 18   shows cross-over probabilities for a 2-path
                Rayleigh fading; and

Fig. 19   shows the peak-to-noise level at cross-over
           probabilities for M=64 and 2-path Rayleigh
           fading.

In the drawings the same or similar reference numerals
denote the same or similar parts throughout. Hereinafter,
embodiments of the invention will be described with
reference to the attached drawings.

Underlying Principle of the Invention

As already explained with reference to Fig. 4, the RAKE
receiver RR is used for handling the multipath propagation
in DS-CDMA systems. A RAKE receiver should be able to
capture most of the received signal energy by allocating a
number of parallel demodulators (fingers) to the selected
strongest components of the multipath signal received from
the antenna. The outputs of all fingers (demodulators) are
combined after the corresponding delay compensation.

The allocation and time synchronization of the demodulators
(fingers) are performed on the basis of an estimated
channel response. The multipath delay search processor
(hereinafter called a searcher) function is to estimate the
channel power delay profile, to identify the paths within
the delay profile and to keep track of changing propagation
conditions. Thus, the multipath delay search processor has
to fullfil the two contradictory requirements of minimizing
the search time and on the other hand to have sufficiently
fine time resolution in order to minimize the PN sequence
self-noise.

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5   The channel impulse response is estimated within a certain
       search window defined by the number of spreading code
       phases which should be searched to cover the maximum
       expected delay spread. The channel impulse response
       estimation is repeated within a certain interval called the
10   update time.

       The update time has to be sufficiently small, such that the
       delay variations of the radio channel can be tracked. The
       position of the channel impulse response within the search
15   window is changing due to the movement of the mobile
       station as well as the clock frequency mismatch between the
       PN sequence generators in the transmitter and the receiver.
       Therefore, the overall position of the search window has to
       be adjusted to keep the channel impulse response in the
20   middle of the search window. When the multipath delay
       search processor (the searcher) has a fine enough
       resolution, the other code tracking devices, usually
       implemented in each of the RAKE single path demodulators,
       are not needed.
25
       The searching and tracking unit STU (see the attached Fig.
       6) of the RAKE receiver (see Fig. 4) is to maintain the
       chip and frame synchronization for the RAKE receiver.
       Therefore, the delay profile of the received signal due to
30   the multipath propagation has to be estimated. As a
       consequence of fading and changing propagation distances,
       i.e. distance variations between the mobile station MS and
       the base station BS, this estimation has to be updated
       according to the specific needs of the mobile radio
35   channel.

       Hereinafter an embodiment of the invention is described,
       where the delay profile of the received signal is estimated

5   with an excellent resolution within a certain search window
    corresponding to the delay spread. The delay profile
    estimation may be repeated within a certain intervall, i.e.
    within the update time. The update time is choosen to be
    sufficiently small, such that delay variations of the radio
10 channel can be tracked. Therefore, no explicit tracking
    needs to be provided. Only the overall position of the
    search window has to be adapted (tracked) to distance
    variations between the mobile station MS and the base
    station BS. Thus, the searching and tracking unit STU can
15 be used to assist the sector selection and softer handover,
    since the sector-assigned delay profiles can be used to
    reveal where the most signal energy can be captured within
    the sectors.

20 In the following it is assumed that any initial sector
    selection, initial frame and initial chip synchronization
    has already been established (e.g. during random access
    signal reception). However, these constraints are no
    principle limitation to this method and the method
25 according to the invention can also be used for this
    purpose by some adaptations.

Embodiment of the Searching and Tracking Unit

30 The searching and tracking unit STU of the invention as
    shown in Fig. 6 comprises a selector SEL to which two
    signals S_1, S_2 received from the antennas Ant1, Ant2 of
    each sector 1...6 are input. The inputting of two signals
    S_1, S_2 to the selector SEL is made, because an antenna
35 diversity technique using two antennas Ant1, Ant2 is
    preferably used in each sector. However, it should be
    understood that the invention is not restricted to the
    antenna diversity in its broader sense and that it is also

5   possible to perform the input of one signal S from one
    antenna of each sector into the selector SEL.

    Of course the signal actually received from the antennas is
    an analog signal. An A/D converter A/D is arranged in the
10 STU means to convert the analog CDMA signal into a digital
    CDMA signal. As shown in Fig. 3, 11, this digital CDMA
    signal comprises consecutive radio frames RF1 ... Rfn
    including consecutive time slots TS1 ... Tsm into which the
    complex pilot symbols PSi and the data symbols PDi are
15 inserted. The A/D converter stands for carrying out all the
    usual functions like analog-digital conversion, matched
    filering, etc. and can be located in the STU means, e.g. in
    the selector SEL, between SEL and the sector antennas or
    before or within the searchers S1 ... SL.
20
    Whilst on the transmitter a digital transmission signal
    including a plurality of bits is first convolutionally
    coded per bit, e.g. with a rate r=1/3, then 2 of the
    convolutionally coded bits are combined as a QPSK symbol
25 (Q, I) and then this symbol is spread with the transmitter
    side PN sequence, the receiver, e.g., RAKE and the
    searchers must likewise despread the symbols with the
    corresponding despreading sequence. This is the basis of
    direct sequence CDMA (i.e. including a QPSK modultation).
30 It is noted that other modulation schemes can be used to
    obtain the symbols to be spread. Therefore the invention is
    not restricted to the usage of QPSK modulation.

    The selector SEL functions to extract the blocks of signal
35 samples to undergo a search in the multipath delay search
    processors S1 ... SL (hereinafter called the searchers S1
    ... SL). Essentially, the respective selector SEL extracts
    the pilot symbols plus some additional samples (symbols for

5   logical channels) out of the data streams received from the
       respective antenna. The frame format and the pilot symbols
       are illustrated in Fig. 3. The extraction of the pilot
       symbols plus the additional samples takes place preferably
       at a sample rate of 16.38 Mega samples per second,
10   essentially at an oversampling rate, for example 4.

       The searching and tracking unit STU in Fig. 6 comprises a
       number of searchers S1 ... SL, wherein L may be the same
       number as the number of sectors or not.
15

       Essentially, the extracted pilot symbols plus the
       additional samples are distributed to the set of L
       searchers according to a specified but flexible sector
       selection schedule. With the sector selection schedule the
20   number of searchers can be different or the same as the
       number of sectors. Preferably six searchers operate at the
       sample rate. On the basis of the block of signal samples
       the extracted pilot symbols plus the additional samples
       (i.e .the demultiplexed and buffered antenna signals)
25   deliver a separate delay profile DPS for each antenna
       signal to the path selection unit PSU according to the
       sector selection schedule.

       According to the invention, the searchers S1 ... SL perform
30   a channel delay estimation (the determination of the delay
       profile) basically by a (pilot symbol based) combined
       coherent and non-coherent searching (and tracking)
       procedure with optional interleaving as will be further
       described with respect to the searcher S1 in Fig. 7.
35   Preferably, the delay profiles DPS are updated at a minimum
       update time and preferably use a predetermined number of
       samples of the pilot symbols.

 5   The path selection unit PSU receives the delay profiles DPS
      from the searchers S1 ... SL and calculates out of the
      estimated delay profiles DPS an interference estimate (this
      interference comprises multi-user interference as well as
      thermal noise power interference), which is used for the
10   succeeding path selection. From the delay profiles DPS
      essentially an interim number of N (preferably 8) paths
      d_1' ... d_N' (i.e. delay values) and corresponding sector
      selection information s_1'...s_N' is determined by the path
      selection unit PSU. The selection information s_1'...s_N'
15   indicates the sector number (1 ... 6) and the antenna
      number in the respective sector (if an antenna diversity is
      not used in each sector, then this number may be omitted).

      Whilst the delay values d_1'...d_N' still indicate an interim
20   number of N (e.g. 8) paths, the tracking and control unit
      TRCU performs the final sector selection and generates a
      final number of (maximum) P (e.g. 8) delay path and
      selection information (i.e. delay values and corresponding
      selection information) that is transmitted eventually to
25   the RAKE receiver RR. Thus, as is seen in Fig. 6, the
      tracking and control unit TRCU outputs the final number of
      delay path
      d_1 ... d_P and the final selection information s_1 ... s_P for
      the final number of paths that should be demodulated and
30   decoded in the RAKE receiver i.e. the paths to which the
      RAKE should allocate its fingers. In addition, the tracking
      and control unit TRCU generates the number of clock control
      signals for tracking the search windows and cells for
      maintaining frame synchronization.
35
      Thus, the antenna signals are input to the selector SEL
      which applies the respective signals from the antennas to a
      number of searchers, which calculate a delay profile for

5   each of the applied input signals. Thereafter, the path
      selection unit selects a number of most promissing paths
      and selection information regarding the sector and the
      number of the antenna. The final tracking and control unit
      determinates the final paths together with the appropriate
10   selection information, such that the RAKE receiver RR is
      supplied with selection information and delay information
      which it can then use for demodulation.

      Hereinafter, specific embodiments according to the
15   invention for the selector SEL (Figs. 7, 8), the searcher
      S1 ... SL (Fig. 7), the path selection unit PSU and the
      tracking and control unit TRCU (Fig. 10) as well as a
      specific embodiment of the despreader DESP and the coherent
      accumulation and averaging unit ACC-AV (Fig. 9) will be
20   described for a frame format as shown in Fig. 3, Fig. 1.

      Embodiment of the Selector Unit

      Fig. 7 shows an embodiment of the selector SEL. The
25   selector comprises a so-called pilot demultiplexer PI-
      DEMUX. Fig. 7 shows the case where one antenna signal is
      input to the pilot demultiplexer PI-DEMUX, but it should be
      understood, that according to the control signals received
      from the control means CNTRL, different antenna signals
30   from different sectors may be successively applied to the
      selector SEL.

      The primary function of the pilot demultiplexer PI-DEMUX is
      to extract and buffer the periods of (consecutive) pilot
35   symbols plus an additional number of samples out of the
      antenna signals which are constituted by input data streams
      of complex values. Considering for example in Fig. 11, that
      for the calculation of one delay profile DPS (calc. 1 DPS)

5   the radio frame n of the antenna signal is evaluated, then
       this frame n consists of a number of consecutive time slots
       k-1, k, k+1.

       As already indicated in Fig. 3, at the transition from one
10   time slot to another, for example from time slot k-1 to
       time slot k, there are a set of pilot symbols PSi
       consisting of pilot symbols of the previous time slot k-1
       and of the pilot symbols of the present time slot k. The
       difference between Fig. 3 and Fig. 11 is that in Fig. 3 the
15   pilot symbols PSi are assumed to only lie at the beginning
       of the time slot whilst in Fig. 11 they lie at the
       beginning and the end of each time slot. Since it can
       anyway not be guaranted that the time slots are already
       time-aligned to the PN sequence generated by the PN
20   generates in the despreader DEsP it does not matter whether
       the sampling and extraction extracts pilot symbols at the
       beginning or the end only (it is a pure matter of
       convention where they lie) as long as it extracts a number
       of pilot symbols and data symbols that can be evaluated
25   with respect to the PN despreading sequence. In between the
       sets of pilot symbols any data may be present, for example
       the symbols for the logical channel etc. as indicated in
       Fig. 3.

30   Now, what is meant with extracting the periods of pilot
       symbols is in fact the extraction of the pilot symbols (the
       shaded areas in Fig. 11). Preferably, 2 M chips (2 M x
       oversampling rate samples, e.g., 2 x 128 = 1024 samples)
       are extracted as pilot symbols. Preferably, additional 160
35   samples (the delay spread) are extracted from the antenna
       signal (the complex input data streams). Thus, the DPS to
       be calculated will eventually consist of 160 real power
       delay spectrum sample values.

5

Therefore, for the delay profile (search window)
estimation, 160 samples at a resolution of four samples per
chip are used, i.e. a delay spread of 160/16.38 Mega
samples per second ≈ 10 μs is evaluated. Preferably, it is

10   also assumed that the minimum update time is 10 ms (i.e.
one radio frame) for recalculating the delay profiles of
the currently active sectors (i.e. a pre-defined number of
sectors, where currently the most signal energy is found)
and an update time of 60 ms for scanning the non-active

15   (i.e. the other) sectors and for selecting the antenna
signals (i.e. re-assigning active and non-active sectors).

Thus, at least in every radio frame of 10 ms (see Fig. 3)
the delay profile is recalculated on the basis of the

20   number of pilot symbols (1024 samples) plus the additional
160 samples, e.g., 8 times based on 2 timeslots). The
additional samples are any kind of data, i.e. control data
or voice data. Depending on the starting timing of
extraction, of course there are cases where first pilot

25   symbols and then data symbols, first data symbols (from the
preceding time slot) then pilot symbols and then again data
symbols or first only data symbols and then only pilot
symbols are extracted.

30   As is seen in Fig. 7, in response to the frame clock
control FCC the control means CNTRL controls the PI-DEMUX
of the selector SEL such that it starts extracting the
pilot symbols and the additional symbols at the correct
timing within the time slots k-1, k, k+1 of the respective

35   frame n.

Fig. 8 shows an embodiment of the pilot demultiplexer PI-
DEMUX. The control signal from the control means CNTRL

26

5   controls a sample switch SSW, which applies the data from
     the antenna signal either to the buffer BUF or to a sink
     SNK. Thus, via the frame clock control signal FCC the
     buffer BUF will contain successively the respective number
     of pilot symbols plus the additional samples. Any other
10   data is applied to the sink SNK.

     Thus, the positioning of the sample switch SSW (i.e. the
     read pointer) and the writing pointer, i.e. the positioning
     of the search window within the overall delay profile and
15   equivalent to inserting or removing samples from the data
     streams, are controlled via the frame clock signals FCC.

     As already mentioned, the control means CNTRL in
     combination with the tracking and control unit TRCU applies
20   control signals to the selector SEL for a sector selection
     of active and non-active sectors according to a specific
     sector selection schedule and furthermore it controls the
     specific assignment of searchers S1 ... SL to the
     demultiplexed antenna signals. Such a sector selection
25   scheduling procedure may preferably be constituted as shown
     in Fig. 13 (to be explained below).

     As described above with reference to Figs. 7, 8, the
     primary function of the selector SEL is to respectively
30   extract a number of pilot symbols plus a number of
     additional samples within each radio frame RFn and to
     successively apply these extracted data values to the
     subsequent searcher for the calculation of the delay
     profile (wherein a sector selection and antenna selection
35   control for providing antenna signals successively from
     several antennas in several sectors to individual searchers
     by the demultiplexer PI-DEMUX is performed). Thus, the
     succeeding delay profile calculation in the set of

5   searchers is based on the extracted pilot symbols and the
extracted additional symbols.

Preferably, the number of the pilot demultiplexers is the
same as the possible number of applied antenna signals,
10   e.g. for the example in Fig. 6 there may be 12 pilot
demultiplexers PI-DEMUX. However, the number can also be
reduced, for example to the pre-defined number of active
sectors according to the sector selection control, if time-
sharing with a corresponding intelligent control is used.
15   Essentially at least one pilot demultiplexer would suffice.

Embodiment of the Multipath Delay Search Processor
(Searcher)

20   As explained above, the output data from the selector (i.e.
the output of the buffer BUF in Fig. 8) are the consecutive
complex pilot symbols plus the additional samples (for
example 2*128 chips = 1024 samples plus 160 samples) from
one particular antenna signal as designated by the control
25   means CNTRL. Hereinafter, the data output by the pilot
demultiplexer PI-DEMUX (i.e. the complex pilot symbols plus
the additional samples) will be referred to as
"demultiplexer output data". As is seen in Fig. 9, of
course the individual demultiplexer output data values
30   comprise a real and an imaginary part Rx_Re and Rx_Im.

As already indicated in the embodiment for the searcher S1
in Fig. 7, the searcher comprises a PN-code generator PN-
GEN generating the despreading sequence to be used in the
35   despreader DESP for despreading the respective demodulator
output data. The code generator PN-GEN and the despreader
DESP as well as the multiplexer PI-DEMUX are controlled in
response to the frame clock control signal FCC processed by

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5 the control means CNTRL. Through this control it is ensured
   that the PN generator despreading sequence is time-aligned
   and - for the calculation of the delay profile DPS -
   shifted to the respective extracted demodulator output
   data. As explained above, the time-alignment is necessary
10 since otherwise there would be a wrong despreading, since
   not only the correct despreading sequence (generated by
   the code generator PN-GEN), but also the correct timing is
   necessary such that the demodulator output data can be
   correctly despread.
15

   As is shown in Fig. 7, the output data from the despreader
   DESP is input to a coherent accumulation/averaging means
   ACC-AV which calculates the delay profile DPS controlled by
   the control means CNTRL. The delay profile is essentially
20 generated on the basis of the demodulator output data (the
   extracted pilot symbols plus the additional samples) in
   response to the frame clock control signal FCC. An
   embodiment of the despreader DESP and the coherent
   accumulation/averaging means ACC-AV according to the
25 invention is shown in Fig. 9.

   The despreader DESP comprises a correlation means CM formed
   by a multiplication means MM and an integration means IM.
   Since the demodulator output data comprise real and
30 imaginary parts and the despreading sequence generated by
   the coded generator PN-GEN must also comprise real and
   imaginary parts, the correlator CM is a complex correlator
   and the multiplication means MM performs a complex
   multiplication. The starting point of the PN-sequence is
35 controlled by the phase control means PH-CNTRL.

29

5   The multiplication means MM comprises multiplexers M1, M2,
    M3, M4 and adders ADD1, ADD2. The integration means IM
    comprises summation units SUM1, SUM2.

    The multiplier M1 multiplies the real part Rx_Re of the
10 demultiplexer output data with the real part PN_Re of the
    spreading sequence and applies the multiplied data value to
    the adder ADD1. The multiplier M2 multiplies the imaginary
    part Rx_IM of the demultiplexer output data with the real
    part PN_Re of the PN sequence. The multiplied signal from
15 the multiplier M2 is input to the adder ADD2. The
    multiplier M3 multiplies the imaginary part Rx_Im of the
    demultiplexer output data with the imaginary part PN_Im of
    the PN sequence and applies the multiplied data to the
    adder ADD1. The multiplier M4 multiplies the real part Rx
20 Re of the demultiplexer output data with the imaginary part
    PN_Im of the PN-sequence and applies the output signal to
    the adder ADD2. The adder ADD1 adds the output signal from
    the multiplier M1 and the output signal from the adder M3
    and applies an added signal to the summation unit SUM1 of
25 the integration means IM. The adder ADD2 adds the output
    signal from the multiplier M2 and an inverted output signal
    from the multiplier M4 and supplies the added signal to the
    summation unit SUM2 of the integration means IM.

30 The multiplication means MM outputs results from the adders
    ADD1, ADD2 for each pilot chip and the summation units
    SUM1, SUM2 perform an addition of the output signals from
    the adders ADD1, ADD2 for N_pilot_chips (e.g. 2 x 128
    times). Since the completed data is a digital signal, the
35 summation performed in the summation units SUM1, SUM2
    correspond to an integration of the output signals from the
    multiplication means MM.

30

5   As one preferred embodiment the PN-generator PN-GEN
       generates the complex quadrature short Walsh Hadamard and
       the real long Gold (Walsh Hadamard) as the despreading
       codes with which the demodulator output data is multiplied.

10   If the complex correlator means CM is driven at an
       oversampling rate OS, only every OS-th complex
       multiplication delivers a non-zero result. Care has to be
       taken if an OQPSK-modulation scheme is applied. Preferably,
       in this case, the complex multiplication performed in the
15   multiplication means MM can be split into two real
       multiplications at a distance of OS/2. The overall code
       phase is adjusted in increments of 1/OS of a chip period. A
       serial search through the time uncertainty region (delay
       spread) with constant dwell time of one pilot symbol period
20   (here: 31.25 μs) at each code phase position (1/OS of a
       chip period) can preferably be applied. Thus, a certain
       number of code phases can be evaluated per slot and
       searcher. Since these operations are done off-line,
       processing at a higher speed can be applied.
25
       The number of evaluable code phases equals the ratio of the
       total number of chips per slot and the numbers of chips per
       pilot symbols times this overprocessing factor OP (here:
       OP*2560/256 = OP*10). One example is a hardware
30   implementation of eight searchers at an overprocessing
       factor OP = 4. Another example is two searchers at OP = 16.

       In the coherent accumulation/averaging means ACC-AV a
       coherent summation unit SUM3 performs a coherent
35   accumulation on the despread values of two consecutive
       periods of pilot symbols (i.e. four pilot symbols in total
       corresponding to two slots). In total, 160 samples of a
       delay profile can be calculated per searcher during 2/OP

5   frames (= 2*16/OP slots), i.e. within the repetition time
       of 20/OP ms. This applies to a searcher with one correlator
       and one despreader. By grouping a number of correlators and
       despreaders within the set of searchers (Fig. 6) a parallel
       searcher architecture can be defined. However, this does
10   not present a limitation of this general description of the
       invention.

       The complex output of the coherent accumulation/averaging
       means ACC-AV, i.e. the real part Re_Imp [Phase] and Im_Imp
15   [Phase] are then input to the squaring unit SQ. In the unit
       SQ the real part and the imaginary part of SUM3 is
       respectively squared and added ($|(a+jb)|^2=a^2+b^2$). The output
       of the unit SQ, namely the partial real delay profile value
       DPS_i is input to the summation unit SUM4 which performs a
20   non-coherent accumulation of the samples. The output from
       the summation unit SUM4 is the actual real delay profile
       DPS. Thus, the summation unit SUM4 essentially averages two
       delay profiles DPS_i from two or more succeeding slots.
       Thus, the underlying principle of the delay profile
25   determination is to perform a complex valued channel
       estimation in each time slot, then to non-coherently add
       the complex channel estimates (complex samples) of at least
       2 time slots and to finally non-coherently add delay
       profiles (real values) of (added) channel estimates from
30   respectively 2 time slots.

       Therefore, the primary function of the despreader DESP can
       be described as multiplying a time-aligned PN-sequence with
       the demodulator output data, whilst the coherent/non-
35   coherent accumulation/averaging means ACC-AV performs an
       averaging over two or more successive slots. The output is
       an averaged delay profile DPS which is based on the

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5   demodulator output data, namely the pilot symbols (+ added
     samples) over one used period for the coherent averaging
     (Fig. 11). Thus, the calculated delay profile DPS is much
     more accurate, since it uses pilot symbols from succeeding
     slots (or frames).

10

     The following example illustrates the functioning of the
     despreaders DESP and the coherent accumulation/averaging
     means ACC-AV. Assuming an antenna diversity in each sector,
     three (active) sectors within a cell with correspondingly

15   six antenna signals can be processed by using 6 searchers
     during two frames for OP = 1. If, as another example, just
     one sector is selected (active), 3 out of the 6 searchers
     can be assigned to each antenna signal. Correspondingly,
     the number of correlations per sample of the delay profile

20   can be increased by a factor of 3. Thus, during 2 frames
     (see Fig. 11) 3 consecutive delay profiles can be computed
     for OP = 1 from which an estimate with reduced peak and
     interference variances can be obtained by averaging. This
     leads to an improved delay profile DPS.

25

     With OP = 16 and 2 searchers, it is possible to calculate
     2*8 (consecutive) delay spectra within the frame period of
     10 ms and 16 time slots. The sector control mechanism (the
     sector scheduling is explained below) can distribute, i.e.

30   allocate this number to active and non-active sectors. For
     example, for two active sectors (two antenna signals each)
     three consecutive delay profiles and for two non-active
     sectors (two antenna signals each) one delay profile can be
     calculated (see Fig. 13). Thus, non-coherent averaging for

35   the active sectors can be applied during each frame. Within
     60 ms, three delay spectra also for the non-active sectors
     can be calculated, thus allowing non-coherent averaging
     also for the non-active sectors.

5

In order to increase the number of non-coherent
accumulations (averaging) in the coherent
accumulation/averaging means by a factor of 2 without
increasing the update time, an "interleaved" averaging

10 scheme according to the invention (see Fig. 11) for an
update time of 10 ms may be employed. Here the last two
consecutive (perhaps already non-coherently averaged) delay
profiles, the currently calculated profile and the profile
of the update time before, are (further) averaged in order

15 to calculate improved delay profiles at an unchanged update
rate of 10 ms. One preferred interleaving scheme for
calculating the delay profiles DPS is for example as
follows. In frame n-1 a delay profile DPS_{n-1} is calculated.
Then in the present frame n a further delay profile DPS_n is

20 calculated. In frame n the two delay profiles are
accumulated (added) non-coherently and the added delay
profile is used as the delay profile DPS_n for frame n, i.e.
$DPS_n' = DPS_{n-1} + DPS_n$. The actually calculated delay
profile DPS_n in frame n is stored to be used for a further

25 accumulation in the next frame n+1. It is also possible to
apply a weighting factor to the previously calculated delay
profile DPS_{n-1}. Instead of just accumulating (non-coherent
adding) of two delay profiles DPS_{n-1}, DPS_n, it is also
possible to store a plurality of preceding delay profiles

30 DPS and then to non-coherently add a plurality of frames to
result in the delay profile DPS for the frame n. The
plurality of delay profiles can also be weighted before the
accumulation. Thus, also different embodiments are possible
that take into account a kind of FIR or IIR filtering (or

35 weighting) of the respective delay profiles DPS.

According to another embodiment of the coherent
accumulation/averaging means, the delay profiles of two

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5   corresponding sector antennas can be added (within the path
      selection unit PSU) (see Fig. 6 and Fig. 10) exploiting the
      antenna diversity. In this case, the coherent
      accumulation/averaging means ACC-AV can preferably add two
      delay profiles from the two different antennas.

10

      On the basis of the final delay profiles DPS output by the
      summation unit SUM4, interference (noise) estimates are
      calculated in the path selection unit PSU. The despreader
      DESP and the coherent accumulation/averaging means ACC-AV

15   are controlled by digital signal processors DSPs, which
      stear the correlation as well as the coherent and non-
      coherent accumulation processes.

      In any case, it is seen that the despreader DSP performs

20   the despreading on the basis of the pilot symbols and the
      coherent accumulation/averaging means ACC-AV performs an
      averaging of delay profiles calculated on the basis of the
      pilot symbols within each frame. The calculation of partial
      delay profiles DPS_i on the basis of pilot symbols is

25   superior to the usage of random data to determine the delay
      profiles. The other aspect of the invention is that
      consecutive delay profiles, at least over two consecutive
      frames, are averaged, thus leading to a more accurate delay
      profile DPS.

30

      ## Embodiment of the Path Selection Unit

      As explained before, the individual searchers S1 ... SL
      each output a delay profile DPS which is calculated on the

35   basis of the periodic pilot symbols and which is preferably
      an averaged delay profile calculated from two succeeding
      frames.

5   Now it will be described how the path selection unit PSU
     selects the predominant paths contained in the delay
     profile DPS. An embodiment of the path selection unit PSU
     is shown in Fig. 10. The function of the PSU will be
     described for the inputting of two delay profiles DPS from
10   two antennas Ant1, Ant2 belonging to the same sector (in
     Fig. 10 it is the sector 1). It should, however, be
     understood that each of the searchers 1 ... L separately
     comprise the equivalent means to respectively output the
     most dominant (strongest) paths in the respective sector.
15   For illustration purposes of the invention it is at this
     point assumed that an antenna diversity is used within each
     sector. However, the invention is not restricted to the
     antenna diversity. Fig. 14 shows the processing of the
     delay profiles in the path selection unit PSU.

20
     The path selection unit PSU comprises an adder ADD, a peak
     detection and removal means PD-RV, a path estimation means
     PEST, a noise estimation means NEST, path verification
     means PVER1, PVER2 and a maximum detection means MAX and a
25   threshold setting means THRS-SET. The noise estimation
     means NEST receives a threshold factor or threshold value
     THRS from the threshold setting means THRS-SET. The primary
     function of this path selection unit PSU, as already
     explained with reference to Fig. 6, is to extract the N-
30   strongest paths d_1' ... d_N' (i.e. delay values) out of the
     respective delay profiles DPS1, DPS2 by taking interference
     (noise) estimates into account. In addition, a selection
     information s_1' ...s_N' is generated, indicating the
     (active) sector (and antenna signals) that have been
35   selected. The delay and selection information which has
     been calculated on the basis of the input delay profiles,
     is passed to the tracking and control means TRCU that
     performs the final selection as indicated in Fig. 6.

5

The path selection unit PSU outputs new strongest paths and
new selection information s_1' ... S_N' at the update time
(e.g. 10 ms), i.e. at the minimum every frame period.

10   Hereinafter, the function of the individual means of the
path selection unit PSU is described with reference to Fig.
10 and Fig. 14.

If default two antenna signals per sector (antenna
15   diversity) or their respective delay profiles DPS1, DPS2
are to be processed, the respective delay profiles DPS1,
DPS2 are first added in the adder ADD. It should be noted,
that the procedure described hereinafter also applies to
the case where the antenna diversity is not used. In this
20   case the adder ADD is omitted and the calculated delay
profile DPS from one antenna per sector is input directly
to the path detection and removal means PD-RV and the path
estimation means PEST. Therefore, the antenna diversity
with two antennas is only a preferred embodiment of the
25   invention.

From the added delay profile DPS' (see step ST1 in Fig. 14)
the overall maximum MAX1 is searched (step ST2). The
maximum MAX1 and a certain number of samples (preferably
30   three depending on pulse spread) on each side of the
maximum (pulse spread) are removed or respectively set to
zero in the peak detection and removal means PD-RV. As
explained before, in total there are a number of 160
samples for each delay profile DPS, such that only the
35   removal of the maximum MAX and three samples to the left
and right does not destroy the complete characteristic of
the delay profile, i.e. essentially the maximum MAX1 should
be removed. The maximum MAX1 and the corresponding delay

5   value d_{MAX1} are stored in the peak detection and removal
     means PD-RV.

     The procedure of maximum removal from the DPS' is repeated
     N-times (step ST4), thus giving a set of N-candidate delay
10   values d_{max1}, d_{max2} ... d_{maxn} and corresponding peak values
     MAX1, MAX2 ... MAXN. The remaining averaged delay profile

     $\overline{DPS^*}$ is considered as interference (noise) from which the
     mean value DPS is calculated in the noise estimation means
     NEST (step ST4). That is, since the relevant maxima have
15   been removed from the added delay profile DPS*, the rest of
     the delay profile DPS* can be considered as but
     interference or noise. Preferably the number of maxima
     should smaller than the number RAKE fingers.

20   Then the stored candidate peak values MAX1, MAX2 ... MAXN

     are compared to the effective noise level $\overline{DPS^*}$ multiplied
     by a certain adaptable but constant threshold factor THRS.
     THRS is gained from an optimization procedure and might
     reflect the number of scanned sectors, the signal-to-
25   interference ratio and the number of non-coherent
     accumulations. Thus, the path estimation means PEST only
     considers those values above the effective noise floor as
     real delay values which correspond to respective
     independent direct and indirect propagation paths not
30   necessarily the direct one.

     If no antenna diversity is used i.e. if only the profile
     DPS of one antenna (and not the added profile) is evaluated
     then the path estimation comes to an end, i.e. the selected
35   maxima that lie above the multiplied threshold are input
     (for each sector) to the maximum detection means MAX, which

5   outputs the delays and the selection information for the N
       highest maxima of all sectors.

       Preferably, if antenna diversity is used, the original
       calculated delay profiles DPS1, DPS2 undergo a further
10   processing in the respective path verification means PVER1,
       PVER2. As seen in step ST5 in PVER1, PVER2 the two delay
       profiles DPS1, DPS2 are independently from each other

       (again) checked against the threshold, i.e. $\overline{DPS^*}$ x THRS.
       Only those maxima in each DPS are kept for each antenna as
15   prospective peaks that still exceed the threshold (of
       course the threshold has to be adapted by a divison of 2 if
       DPS1 + DPS2 was not normalized by ½). Thus, now the final
       selected paths - per antenna and sector indicated by the
       selection information - are determined.
20

       At this point, the output of the maximum detection means
       MAX is - by having evaluated all sectors (for example six
       sectors) with respect to their input N maxima - a measure
       of the most relevant delays d_1, ... d_N, as well as the
25   selection information from which sector these strongest
       maxima and their delays originated. Thus, the output of the
       maximum detection means MAX, i.e. in fact the output of the
       path selection unit PSU, is a measure of the propagation
       paths that carry the most energy (i.e. the most important
30   delays plus an indication where (i.e. in which sector)
       these path delays have occured. The maximum detection means
       orders the maxima in a descending order from the highest to
       the lowest maxima (with a corresponding adaptation of the
       selection informations).
35

       By adapting the sector selection method (the sector
       selection scheduling) and by adjusting the correlation
       process as will be described below, a trade-off between the

5   number of active and non-active sectors, the update time
     and accuracy of the calculated delay profiles can be made.
     That is, by performing an appropriate search through the
     individual sectors (see Fig. 12) and by distinguishing
     between active and non-active sectors, an even more
10   accurate delay profile and a determination of the movement
     of the mobile station between sectors can be calculated.
     Apart from the calculation of an improved delay profile,
     the sector selection procedure can also be used for a
     softer hand-over, i.e. generally for a more accurate
15   determination of where the mobile is located and/or whether
     the mobile is located on the boarder line between two
     sectors.

     Hereinafter, the function of the tracking and control unit
20   TRCU shown in Fig. 6, which receives the above described
     output from the path selection unit PSU, will be described.

Embodiment of the Tracking and Control Unit

25   As is seen in Fig. 6, the tracking and control unit TRCU
     receives the output from the path selection unit PSU (see
     Fig. 10), i.e. the delay times $d_1' \ldots d_N'$ of the most
     relevant maximum values obtained from all path verification
     means PVER1, PVER2 of all sectors as well as the specific
30   selection information $s_1' \ldots s_N'$ indicating to which
     sector and which antenna the respective delay time belongs.
     The unit TRCU now selects the P strongest maxima from the
     output of the unit PSU (P = number of RAKE fingers), i.e.
     the delay values $d_1 \ldots d_P$ and the respective selection
35   information $S_1 \ldots S_P$.

     However, of course the values output by the path selection
     unit PSU as such are only valid as long as a fixed position

40

5   (and distance) between the mobile station MS and the base
       station BS is maintained. If the position is varied, which
       is the normal case, then of course the power delay spectrum
       DPS, i.e. the delay times, might change. Now, of course
       each search means S1 ... SL may use a predetermined window
10   for determining the power delay spectrum. That is, the
       phase of the code generator PN-GEN (with its oversampled
       despreading sequence) or the signal sequence itself by
       inverting or removing samples by the pilot demultiplier is
       shifted a predetermined number of spreading symbols and
15   this shifting corresponds to evaluating a predetermined
       delay time. Of course, during a first transmission set up
       between the mobile station MS and the base station BS, a
       predetermined average delay time will apply even to the
       direct path P1. During this time a predetermined window of
20   shift distances (delay spread) can be determined. However,
       the center value of the delay spread window must be shifted
       corresponding to a distance change between the mobile
       station MS and the base station BS if the mobile station MS
       moves around. Different strategies are thinkable.

25

       Therefore, the first function of the tracking and control
       unit TRCU is to adapt (track) the (delay spread) search
       windows to distance variations between MS and BS. It will
       not do so continuously, but preferably a minimum update
30   time of 10 ms (length of a radio frame) will be sufficient
       (OP = 16, 2 searchers, 2 active sectors, 3 non-coherent
       averagings without interleaving). The buffers included in
       the pilot demultiplexers of the selector SEL are controlled
       by insertion or removal of samples (of the pilot symbols
35   and data symbols) by adjusting the read and write pointers
       within the pilot demultiplexer. By shifting the read and
       write pointers in the demultiplexer, different start and
       end timings of the extraction of the pilot symbols plus the

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5 additional samples are achieved which corresponds to a
   shifting of the values resulting effectively in a change of
   the search window. Another possibility is to shift the PN-
   generator phase as explained above.

10 During a sector (softer) hand-over a common search window
   off-set is applied to both adjacent sectors in order to
   maintain synchronization. This common search window off-set
   is therefore also usable for (adjacent) non-active sectors
   (where no substantial power delay spectrum, i.e. no
15 detectable paths, can be calculated/expected). Algorithms
   for adapting the search window to mobile movements or
   distance variations (resulting in varying delays) can
   easily be deviced by those skilled in the art, by
   considering for example the movement (delay) of the highest
20 maximum MAX1 over time.

   Apart from the shifting of the search window employed in
   the searcher, the tracking and control unit TRCU has
   another function, to also update the already calculated
25 delay path d_1' ... d_N' according to the adjustments of the
   search window and to select a certain number of final delay
   values d_1 ... d_p and corresponding antenna/sector
   information d_1 ... d_p.
   (P = number of the RAKE fingers).
30
   Thus, each PVERn unit is delivering a set of "candidate"
   peaks. All peaks are arranged in a descending order by the
   maximum detection unit MAX and only the P largest are
   maintained (irrespective what sector they are from) by the
35 unit TRCU.

   This procedure is carried out for all antennas of all
   active sectors and out of all "survivors" amongst all

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5   investigated antenna signals of all active sectors a
      sequence of pre-defined maximum length (i.e. adapted to the
      number of RAKE fingers, e.g. $p = 8$) in descending order
      with respect to the power of the maximum values is
      arranged. This sequence now reflects the strongest paths
10   found within all currently investigated antenna signals
      (this will normally reflect the active sectors but might
      also include - currently still-non-active sectors).
      Simultaneously with the selection of the new delay values
      $d_1 \ldots d_p$ according to the new descending order, of course
15   .the selection information will also be updated to indicate
      the location of the respective delay times, i.e. to
      indicate the respective sectors belonging to the respective
      delay times. This selection information will tell the RAKE
      receiver connected to the output of the searching and
20   tracking unit STU which signals have to be demodulated. If
      less than this maximum number of path are identified, the
      RAKE receiver gets information that some RAKE fingers have
      to be switched off (e.g. by setting the respective
      selection information s to a negative value).
25

      It is to be noted that the above-described updating of the
      delay times and the selection information output by the
      path selection unit PSU is not restricted to the case of
      antenna diversity. If only a single antenna per sector is
30   used then only one delay profile need to be examined.

      As was already explained above, the number of sectors and
      the number of searchers are not necessarily the same.
      Preferably, the set of searchers consists of six searchers
35   in total. However, the number of sectors may be larger or
      smaller or equal to the number of searchers. Therefore, the
      control means CNTRL in Fig. 6 controls the selector SEL
      such that the individual antenna signals (one or two per

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5   sector) are applied to the respective searchers in a time-
     shared manner.

     <u>Sector Selection Scheduling</u>

10   As was also explained above, in the present invention the
     searcher preferably calculates a delay profile on the basis
     of pilot symbols extracted from at least two consecutive
     time slots within each frame. As indicated in Fig. 11, each
     frame, however, consists of 16 time slots. Assuming a case
15   where the (single) antenna signal is applied by the
     selector SEL to one individual searcher over the complete
     frame period of 10 ms, then obviously the searcher could
     not only perform a calculation of the final delay profile
     by only once evaluating two consecutive time slots, but in
20   fact the searcher could - for this antenna signal - carry
     out the calculation in total eight times for this antenna
     signal (16 time slots). However, the control means CNTRL
     can switch at two other time slots to another antenna
     signal after having performed the time slot computation for
25   the present antenna signal (since in fact after the first
     computation using two time slots there is time amounting to
     14 other time slots). Hereinafter, it is explained how the
     sector scheduling, i.e. the application of antenna signals
     to a set of searchers each performing the computation of
30   data in two consecutive time slots - can preferably be
     performed. It is however noted that the unit TRCU can also
     use a (non-optimal) sector scanning rule which is preset
     for a predetermined number of sectors for each cell.

35   Firstly, the tracking and control unit TRCU determines
     which of the sectors are active sectors and which of the
     sectors are non-active sectors. The selection information
     $s_1 \ldots s_p$ in connection with the delay times $d_1 \ldots d_p$

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5   indicate which of the presently available sectors are
       active or non-active. That is, sectors, which are active,
       are indicated in the selection information.

       Secondly, the tracking and control unit TRCU (or the
10   control means CNTRL, respectively) decides how many
       coherent accumulations can be performed in one frame. As
       explained above, if the complete frame for example contains
       16 time slots, this will indicate that in total 8
       independent coherent accumulations can be performed in a
15   frame (based on 2-slot coherent channel estimations. That
       is, the number of coherent accumulations which can in
       principle be carried out in one frame is the number of time
       slots divided by 2.

20   Next, the tracking and control unit TRCU determines the
       number of non-coherent accumulations, that is, the number
       of separate DPS_i calculations (respectively done by
       considering two consecutive time slots) which are then
       added up non-coherently (i.e. their absolute values are
25   added).

       Next the tracking and control unit TRCU determines the
       update time for the power delay spectrum updating (i.e. the
       window shifting). The updating time essentially means the
30   period after which the same two time slots in the same
       sector for calculating the same DPS profile need to be
       looked at. The update time for active sectors need not
       necessarily be the same as in non-active sectors. That is,
       since the major changes (distance changes) will occur in
35   the active sectors, the non-active sectors need not be
       looked at so often, i.e. their update time may be larger.
       However, to have the same accuracy for the delay profile
       calculation, preferably the number of non-coherent

45

5   accumulations should be the same in the active sectors and
        the non-active sectors.

        Finally, the tracking and control unit TRCU and the control
        means CNTRL - in order to determine the scheduling - must
10   know how many searchers S1 ... SL are available. That is,
        if there are more searchers that work parallely, of course
        more sectors can be scanned within each frame.

        Thus, the tracking and control unit TRCU determines at
15   anyone time the scanning scheduling of the sectors on the
        basis of the number of active and non-active sectors (as
        indicated by the selection information), the number of time
        slots per frame (determining the number of possible
        coherent accumulations), the number of non-coherent
20   accumulations desired for the active sectors and the non-
        active sectors, the desired up-date times for the active
        and non-active sectors as well as on the basis of the
        number of sectors (fixed) and the number of searchers (also
        fixed).
25
        Of course, once the scanning schedule has been determined
        the scanning of sectors using this particular scanning
        schedule only makes sense as long as the sector status
        (indicated by the selection information) stays the same.
30   That is, if one non-active sector suddenly becomes an
        active-sector (due to a movement of the mobile station)
        then a different scanning schedule is set by the tracking
        and control unit. With such a scheduling scheme, of course
        the movement of the mobile station from one sector to
35   another sector accross a sector boundary can be decided in
        a "soft" manner. That is, if the mobile station moves from
        one active sector in a direction towards a non-active
        sector then at some stage the receiving antenna in the non-

5   active sector will start to receive a signal and if the
     mobile station is close to the boundary the previously non-
     active sector will exhibit a delay profile including maxima
     which will indicate that the sector becomes active.
     However, the decision process is not a hard decision
10   process, since essentially with the sector scanning a
     continuous movement of the mobile station can be monitored.

     It is also possible that two sectors are declared as active
     ones, the other 4 as non-active. The assignment of the
15   sectors as active or non-active may change, but the number
     of active-non-active (similar: 3 active - 3 non-active
     etc.).

     The following Table 1 in connection with Fig. 13, Fig. 15
20   shows an example of such a sector scheduling. In this
     example it has been assumed that the entire frame is 10 ms
     long and contains 16 time slots resulting in the potential
     possibility of handling 8 coherent accumulations.

25   For the case of 1 active/5 non-active sectors, update times
     for the non-active sectors were allowed to be 50 ms, 10 ms,
     20 ms, 30 ms, respectively. For the active sectors an
     update time of 10 ms, i.e. every frame, is required.

30   In the case of 2 active/4 non-active sectors, the non-
     active sectors are allowed to have an update time of 10 ms,
     20 ms, 60 ms, respectively.

     In the case of 3 active sectors 3 non-active sectors an
35   update time of 30 ms is requested for the non-active
     sectors. The number before the update times in brackets
     indicate the possible number of coherent accumulations.

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In fact, in Table 1 it has been prespecified that two searchers with an oversampling rate of OP = 16 and a requested update time of 10 ms for each active sector are used. Also, a minimum number of two non-coherent accumulations is requested. The circuit configuration for this is shown in Fig. 15. A control signal CNTRL will indicate to the selector the timing when the respective first and second antenna of each sector is applied to the first and second searcher S1, S2. In Fig. 15 it is assumed that the first antenna is always handled by the first searcher S1 and the second antenna is always handled by the second searcher S2.

In Table 1 the cases where the number of non-coherent accumulations is the same and their respective update times are indicated in a bold-face frame. For example, for the case of 2 active sectors/4 non active-sectors the non-active sectors only need to be updated after 6 frames (60 ms), wherein the active sectors are updated after every frame (10 ms). However, the same number of non-coherent accumulations (3) are employed. Obviously putting different constraints on the update times, for example increasing the update times for the non-active sectors will allow more non-coherent accumulations.

Table 1

1 active	5 non-act.	2 active	4 non-act.	3 act.	3 non-act.
7 (10 ms)	1 (50 ms)	2 (10 ms)	1 (10 ms)	2 (10 ms)	2 (30 ms)
6 (10 ms)	2 (50 ms)	2 (10 ms)	2 (20 ms)		
5 (10 ms)	3 (50 ms)	3 (10 ms)	1 (20 ms)		
4 (10 ms)	4 (50 ms)	3 (10 ms)	2 (40 ms)		
3 (10 ms)	1 (10 ms)	3 (10 ms)	3 (60 ms)		
3 (10 ms)	2 (20 ms)				
3 (10 ms)	3 (30 ms)				

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5   The aforementioned example of 2 active sectors/4 non-active
     sectors with update times of 10 ms, 60 ms and three non-
     coherent accumulations (using an antenna diversity in each
     sector and 2 searchers) give the most relevant information
     as to how the sectors must be scanned. Whilst the update
10   times determine how often a sector must be looked at, it,
     however, does not exactly specify the sequence of
     scannings. Fig. 13a), b) show two different scanning
     sequences. In Fig. 13 "A" denotes an active sector, the
     number following "A" denotes the first, second and third
15   active sector and the subscript following this number
     denotes the number of the DPS calculation (i.e. the
     coherent accumulation performed over 2 time slots). "N"
     denotes a non-active sector.

20   In Fig. 13a) the three coherent accumulations 1, 2, 3 for
     the active sector 1, $A1_1$, $A1_2$, $A1_3$ and the three DPS
     calculations for the second active sector, $A2_1$, $A2_2$, $A2_3$,
     are successively performed. There are four time slots left
     in frame 1 which are respectively used for performing the
25   first DPS-calculation in the non-active sectors $N1_1$, $N2_1$.
     The update time of 10 ms for the active sectors can be seen
     in frame 2, since after every 10 ms the same sequence of
     DPS calculations is used for the active sectors. However,
     the remaining four time slots can respectively be used for
30   a scanning of the non-active sectors N1, N2 for their
     respective second DPS calculation, $N1_2$, $N2_2$. The scanning
     of the active sectors is maintained in every frame wherein
     in every frame the last four time slots are used for the
     scanning of the non-active selectors. Since the update
35   period for the non-active sectors has been selected to 60
     ms, the sequence of scannings in frame 1 regarding the non-
     active sectors is only repeated in the 7th frame (not
     shown) which is in fact the same as frame 1.

5

Fig. 13b) shows another realization of the scheduling as
prescribed by the parameters in Table 1. Here, the sequence
of scannings of active-sectors and non-active sectors has
been changed, whilst still the constraints as given in

10   Table 1 are fulfilled. Therefore, there is some freedom in
still arranging the scannings within each sector.

Depending on how the scanning of the non-active sectors
with respect to their first, second and third coherent DPS

15   calculation is performed, after every third DPS calculation
a non-coherent accumulation can take place and the delay
profiles can respectively be evaluated for changes. When
the mobile station moves around, the delay profiles will
change their shape (due to different multipath

20   propagation), however, overall the path selection unit will
still indicate that the sector is active, even though the
delay profile has changed. Evaluating the delay profile in
one active sector with respect to the delay profile in one
or more adjacent active sectors can give an estimation as

25   to the direction in which the mobile station moves. Even if
the delay profile in the non-active sectors, as long as
they stay non-active, do not contain any maxima (paths)
that would exceed the defined threshold level, the delay
profiles of the non-active sectors can nonetheless be

30   evaluated together with the active-sectors, since even the
delay profile in a non-active sector will change if the
mobile station moves from a non-active sector in the
direction of an active-sector.

35   Thus, by evaluating the delay profiles as soon as all non-
coherent accumulations have been performed in all sectors
(in the example in Fig. 13 after 60 ms) all delay profiles
can be evaluated together which gives an estimate of the

5   location of the mobile station within the cell and of the
    moving direction of the mobile station.

Performance of the Inventive CDMA Base Station

10 Hereinafter, a CDMA base station including 6 searchers with
    OP=1 is investigated.

    The performance of the searching and tracking algorithm is
    characterised by the detectability of channel paths from
15 the delay profile. Channel paths become visible in the
    estimated delay profile as autocorrelation peaks. The
    estimation algorithm must be capable to reveal these
    autocorrelation peaks at a reasonable signal-to-
    interference ratio above interference level. The path
20 detectability depends on the signal-to-interference ratio
    in the RF band and the despreading gain of the searching
    algorithm as well as the peak and noise variances. The
    despreading gain of the searching algorithm is defined by
    the despreading gain per pilot symbol and the number of
25 coherent accumulations of despread pilot symbols.

    For the proposed algorithm this despreading gain equals,
    e.g., $10*\log 128*4 = 27$ dB. The signal-to-interference
    ratio E_{ch}/l_0 seen by the channel estimation (i.e. the
30 distance between autocorrelation peak and noise floor in
    the estimated delay profile) is by, e.g., $10*\log 512/M$ (in
    dB) higher than the $E_s l_0$ per modulation symbol, where $M \in$
    $\{16,32,64,128)\}$ is the modulation symbol spreading factor.
    Since a rate 1/3 convolutional code and a quarternary
35 modulation scheme is applied, the E_{ch}/l_0 is by $10*\log$
    $2*512/3M$ (in dB) larger than the corresponding E_b/l_0. The
    peak and noise variances decrease with an increasing number

5   of non-coherent averagings, i.e. the detection probability
     increases and the false alarm probability of detecting a
     non-existing peak decreases.

     Figure 16, 17 show examples of the probabilities of non-
10   detecting an existing peak and, in contrary, of detecting a
     non-existing peak ("false alarm") for a 2-path, equal
     strength, independently Rayleigh fading channel, v=50 km/h,
     $M = 64$ and $E_b/1_0 = 5$ dB. The underlying update time was 20
     ms (6 searchers, OP=1). Antenna diversity and the
15   interleaved averaging scheme was applied. The curves are
     plotted versus the peak-to-interference threshold, i.e. the
     (normalised) ratio of peak and corresponding noise values.
     Different curves for the non-detection probability are
     shown: Detection ranges (DR) of 0, 1 and 2 samples were
20   investigated. This means that all peaks are counted as
     correctly detected if they exceed the peak-to-noise level
     and if their corresponding delay value lies within the
     interval
     [correct_delay-DR correct_delay+DR]. 'any peaks' means that
25   all peaks above peak-to-noise level without checking their
     actual delays were counted. As can be seen the strict
     evaluation with DR=0 leads to some performance loss.
     However, for DR=1 and, especially, DR=2 no significant loss
     with respect to the non-detection probability can be
30   identified.

     Figure 18 shows the performance of the algorithm over
     $E_b/1_0$. The probability values at the intercept points as
     depicted in figure 17 were taken. For practical purposes
35   the threshold factor should be slightly increased to
     provide more security against false alarms introducing a
     slight performance degradation.

52

5   Figure 19 gives an impression how an optimal threshold
    factor is dependent on the signal-to-noise ratio, the
    number of (scanned) sectors and (inherently) the number of
    non-coherent accumulations.

10 **Industrial Applicability**

    The proposed invention can be used in any (periodically)
    pilot symbol based transmission scheme for delay profile
    estimation and path detection. It is a very prospective
15 candidate with respect to constraints on hardware
    expenditure, flexibility and accuracy of the profile and
    noise estimations. That is by adapting the number of
    searchers in combination with the proposed scheme of
    coherent and non-coherent accumulations (OP interleaved
20 averaging scheme) nearly any trade-off between accuracy and
    hardware expenditure can be achieved. Non-coherent
    averaging is applied in order to reduce peak and noise
    variances. A wide variety of sector selection schemes
    (scheduling) can be applied.
25
    This description, the preferred embodiments and examples of
    the invention as presently perceived as the best mode of
    the invention have been described. However, it is obvious
    that various modifications and variations of the invention
30 are possible for a skilled person in view of the above
    technical teachings. Therefore, the invention should not be
    seen as being resticted to the above-described embodiments
    and examples and the scope of the invention is defined by
    the attached claims. In the claims, reference numerals only
35 serve clarification purposes and do not limit the scope of
    these claims.

5

Claims

1.   A multipath propagation delay determining means (STU,
10   Fig. 6, 7) for determining a power delay spectrum
         (DPS) of a CDMA signal transmission between a CDMA
         base station (BS) and a CDMA mobile station (MS) on a
         plurality of propagation paths (P1, P2) within a cell
         (CL) of a CDMA communication system, comprising:

15

     a)   an A/D conversion means (A/D) for converting an
           analog CDMA multipath signal (S_1, S_2) received
           from at least one antenna (Ant1, Ant2) within
           said cell (CL) into a digital CDMA multipath
20   signal (S_1, S_2) consisting of consecutive radio
           frames (RF1...RFn) including consecutive time
           slots (TS1...TSm) with complex pilot symbols
           (PSi) and data symbols (PDi);

25   b)   a demultiplexing means (PI-DEMUX) for extracting
           complex pilot symbols (PSi) and data symbols
           (PDi) from at least two consecutive time slots
           (TSk-1, TSk, TSk+1) of each radio frame (RFn) and
           for storing them consecutively in a memory means
30   (BUF) thereof; and

     c)   a searching means (S1...SL) for determining a
           power delay profile (DPS, DPS1, DPS2, Fig. 14) of
           said each antenna (Ant.1, Ant.2) on the basis of
35   said extracted and stored complex pilot symbols
           and said data symbols (PSi, PDi).

5   2.   A means (STU, Fig. 6, 7) according to claim 1,
           characterized by

     c1)   a despreading sequence generator (PN-GEN) for
           generating a predetermined despreading sequence
10   (DESP-SQ);

     c2)   a despreading means (DESP, C̲M̲, MM, IM) for
           despreading each of said complex pilot symbols
           (PSi; Rx_Re, Rx_Im) with said despreading
15   sequence (DESP-SQ; PN_Re, PN_Im) to output
           complex despread pilot values (PSi', Rx_Re',
           Rx_Im') for each time slot (TSk-1, TSk, TSk+1);

     c3)   an averaging means (ACC-AV) for averaging said
20   despread complex pilot values (PSi', Rx_Re',
           Rx_Im'), comprising:

           c31) a coherent accumulation means (SUM3) for
                 coherently adding the real and imaginary
25   parts (PSi, Rx_Re', Rx_Im') of corresponding
                 despread complex pilot symbols (PSi)of at
                 least two consecutive time slots (TSk-1,
                 TSk, TSk+1) into one complex power delay
                 spectrum sample value ($\overline{DPSi}$, Re_Imp(Phase),
30   Im_Imp(Phase));

           c32) an absolute value determining means (ABS)
                 for outputting one real power delay spectrum
                 sample value (DPSi) by determining the
35   absolute value of said one complex power
                 delay spectrum sample value ($\overline{DPSi}$,
                 Re_Imp(Phase), Im_Imp(Phase)); and

55

c33) a control means (PN-CNTRL) for successively
    shifting the phase between said despreading
    sequence generated by said despreading
    generator (PN-GEN) and said extracted and
    stored pilot sysmbols (PSi) and said data
    symbols (PDi) a predetermined number of
    times , wherein said absolute value
    determining means (SQ) outputs as a real
    power delay spectrum (DPS) a predetermined
    number of real power delay spectrum sample
    values (DPSi) dependent on the phase shift.

3. A means (STU; Fig. 7, 9) according to claim 1,
   characterized in that
   it is incorporated in a CDMA base station (BS; Fig. 7,
   9) or in a CDMA mobile station.

4. A means (STU; Fig. 7, 9) according to claim 2,
   characterized in that
   said despreading means (DESP, CM, MM, IM), said
   coherent accumulation means (SUM3) and said absolute
   value determining means (ABS) determine at each phase
   shift a plurality of real power delay spectrum sample
   values (DPSi) each value being based on the coherent
   addition of corresponding despread complex pilot
   symbols in at least two respective consecutive time
   slots, wherein the at least two consecutive time slots
   used for one value are different to those used for
   another value;

   a non-coherent accumulation means (SUM4) is provided
   for non-coherently adding the corresponding real power

5   delay spectrum sample values to output one real power
delay spectrum sample value (DPS).

5.   A means (STU; Fig. 5, 6) according to claim 1,
characterized by

10   a path selection unit (PSU) for determining from said
real power delay spectrum (DPS) the delay times
$(d_1'...d_N')$ of a predetermined number of propagation
paths (P1, P2) of said multipath transmission.

15 6.   A means (STU; Fig. 6) according to claim 3 and 5,
characterized by

a tracking and control unit (TRCU) for adapting a
search window used in the at least searching unit
(S1...SL) and for updating the power delay spectrum

20   (DPS) and the delay times $(d_1'...d_N')$ according to
position and/or distance variations between said
mobile station (MS) and said base station (BS).

7.   A means (STU; Fig. 1, 6, 12) according to claim 3,

25   *characterized in that*
said CDMA cell (CL) served by said CDMA base station
(BS) is subdivided into a predetermined number of
sectors (SECT1...SECT6) each comprising at least one
antenna (Ant1, Ant2) and said A/D conversion means

30   (A/D) converts all of said antenna signals into a
corresponding digital CDMA multipath signal (S_1, S_2);

a predetermined number of searching units (S1...SL) is
provided; and

35

a selection means (SEL) is provided for applying said
digital CDMA multipath signals (S_1, S_2) to said

5   individual searching units (S1, SL) in response to an
         application control sequence output by a control means
         (CNTRL).

8.   A means (STU; Fig. 6) according to claim 7,
10   *characterized in that*
         each sector (SECT1...SECT6) contains two antennas
         (Ant1, Ant2) and said selection means (SEL) applies
         the converted digital CDMA multipath signals ($S_1...S_2$)
         from each sector (SECT1...SECT6) respectively to one
15   searching unit (S1...SL).

9.   A means (STU; Fig. 6, 12) according to claim 7 or 8,
         characterized in that
         the number of sectors (SECT1...SECT6) equals the
20   number of searching units (S1...SL).

10.   A means (STU; Fig. 6, 12) according to claim 7 or 8,
         characterized in that
         the number of sectors (SECT1...SECT6) is smaller or
25   larger than the number of searching units (S1...SL).

11.   A means (STU; Fig. 8) according to claim 1,
         characterized in that
         said demultiplexing means (PI-DEMUX) comprises a
30   switching means (SSW), said memory means (BUF) and a
         sink means (SNK), wherein a control means (CNTRL)
         controls said switching means (SSW) in response to a
         frame clock control signal (FFC) to consecutively
         transfer said extracted complex pilot symbols and data
35   symbols into said memory means (BUF) and transfers
         other data symbols of said time slots into said sink
         means (SNK).

12. A means (STU; Fig. 9) according to claim 2,
   characterized in that
   said despreading means (DESP) comprising a complex
   correlator (CM) consisting of a multiplication means
   (MM) and an integration means (IM).

13. A means (STU; Fig. 9) according to claim 12,
   characterized in that
   said multiplication means (MM) comprises a first,
   second, third and fourth multiplier (M1, M2, M3, M4)
   and a first and second adder (ADD1, ADD2), wherein the
   first multiplier (M1) multiplies the real part (Rx_Re)
   of each pilot symbol with the real part (PN_Re) of a
   symbol of said despreading sequence, said second
   multiplier (M2) multiplies the imaginary part (Rx_Im)
   of said pilot symbol with the real part (PN_Re) of a
   symbol from said despreading sequence, said third
   multiplier (M3) multiplies the imaginary part (Rx_Im)
   of each pilot symbol with the imaginary part (PN_Im)
   of said symbol of said despreading sequence, said
   fourth multiplier (M4) multiplies the real part
   (Rx_Re) of each pilot symbol with the imaginary part
   (PN_Im) of said symbol of said despreading sequence,
   said first adder (ADD1) adds the outputs from the
   first and third multiplier (M1, M3) and said second
   adder (ADD2) adds the outputs of said second and said
   fourth multipliers (M2, M4), wherein said integration
   means (IM) comprises a first and second summation unit
   (SUM1, SUM2) which respectively add the values output
   from said first and second adder (ADD1, ADD2) over a
   predetermined number of pilot chips (N_pilot_chips),
   wherein said first and second summation unit (SUM1,
   SUM2) respectively output the real and the imaginary

5   part of said complex despread pilot values (PSi',
           Rx_Re', Rx_Im').

14.   A means (STU; Fig. 10, Fig. 14) according to claim 5,
           characterized in that said path selection unit (PSU)
10   comprises:

           a peak detection/removal means (PD-RV) for detecting a
           predetermined number of peaks (MAX1, MAX2, MAXn) in
           said power delay spectrum (DPS) and for setting zero
15   or removing at least those samples of said real power
           delay spectrum (DPS) corresponding to the detected
           peaks and a predetermined number of additional samples
           left and right to said maximum;

20   a noise estimation means (NEST) for averaging the real
           power delay spectrum (DPS) having the peak samples and
           said additional samples set to zero or removed to
           determine an effective noise value; and

25   a path estimation means (PEST) for selecting delay
           times $(d_1'...d_N'; d_{max1}, d_{max2}, d_{maxN})$ of the
           determined peaks which exceed a threshold $(\overline{DPS^*} \times$
           THRS) formed by multiplying the effective noise value
           with a threshold factor (THRS).
30

15.   A means (STU; Fig. 10, 14) according to claim 8,
           characterized in that said path selection unit (PSU)
           further comprises:

35   an adder (ADD) to sum up a first and second real power
           delay spectrum (DPS1, DPS2) of the two antennas (Ant1,
           Ant2) per sector, wherein the peak detection and

removal means (PD-RV) detects and zeros peaks in said
added real power delay spectrum (DPS');

a first and second path verification means (PVER1,
PVER2) for comparing the multiplied threshold ($\overline{DPS^*}$ x
THRS) determined by said path estimation means (PEST)
respectively with said first and second real power
delay spectrum (DPS1, DPS2) of each antenna at the
determined delay values (d_{max1}, d_{max2}, d_{maxN}) wherein
only such peaks in the first and second power delay
spectrum are detected which are equal or above the
multiplied threshold.

16.   A means (STU; Fig. 10) according to claim 15,
      characterized by
      a maximum detection means (MAX) for receiving the
      candidate peaks from the respective path verification
      means (PVER1, PVER2) from a plurality of search means
      (S1...SL) each serving one or more sectors
      (SECT1...SECT6) and for ordering a predetermined
      number (N) of highest peaks as well as their delay
      times ($d_1'...d_N'$) output by the path verification
      means (PVER1, PVER2) of the respective search means
      (S1...SL) in a descending order and for determining a
      selection information ($s_1'...s_N'$) for each delay time
      ($d_1'...d_N'$) indicating to which sector (SECT1...SECT6)
      the respective delay times ($d_1'...d_N'$) belong.

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17. A means (STU; Fig. 3, 11) according to claim 2,
     characterized in that
     said radio frames (RFn) each comprise sixteen time
     slots, wherein a plurality of real power delay spectra
     (DPS) are calculated non-coherently.

18. A means (STU; Fig. 6, 13, 15) according to claim 6 and
     16, **characterized in that**
     said tracking and control unit (TRCU) receives said
     selection information values $(s_1'...s_N')$ and said
     delay times $(d_1'...d_N')$ and selects a predetermined
     number (P) of delay times $(d_1...d_P)$ and corresponding
     selection informations $(s_1...s_P)$.

19. A means (STU; Fig. 6, 13, 15) according to claim 18,
     characterized in that
     said tracking and control unit (TRCU) uses a
     predetermined sector scanning rule for the currently
     active and non-active sectors as indicated by said
     selection information $(s_1'...s_N', s_1...s_P)$ for
     instructing said selection means (SEL) to apply the
     respective antenna signals (Ant1, Ant2) from the
     respective sectors (SECT1...SECT6) to said number of
     search units (S1...SL) according to said predetemined
     sector scanning rule.

20. A means (STU; Fig. 6, 13, 15) according to claim 19,
     characterized in that
     said tracking and control unit (TRCU) determines, on
     the basis of the number of time slots (TSi) in each
     radio frame (RFn), the number of total sectors
     (SECT1...SECT6), the number of search means (S1...SL),
     a predetermined update period (10ms) for active

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sectors and the number of currently active and non-active sectors as indicated by said selection information ($s_1'...s_N'$, $s_1...s_p$), a predetermined number of coherent and non-coherent calculations of the real power delay spectrum (DPS) and the update period for non-active sectors (SECT1...SECT6), said sector scanning rule (Fig. 13a, 13b) indicating which sector is to be scanned at each respective time slot (Tsi) of each radio frame (RFn).

21. A means (STU; Fig. 6, 13, 15) according to claim 19 or 20, *characterized in that*
     said tracking and control unit (TRCU) evaluates changes in the respective real power delay spectra (DPS) over time in each active and non-active sector with respect to each other in order to determine the moving direction and the sector of the cell (CL) in which said mobile station (MS) moves.

22. A means (STU; Fig. 6, 13, 15) according to claim 19 or 20, *characterized in that*
     said tracking and control unit (TRCU) selects a new sector scanning rule whenever a status of a scanned sector changes from active to non-active or vice vica.

23. A means (STU; Fig. 6) according to claim 3, *characterized in that*
     said multipath propagation delay determining means (STU) is connected to a RAKE receiver (RR) of said CDMA base startion (BS) or said mobile station (MS).

24. A multipath propagation delay determining means (STU, Fig. 6, 10) for determining real power delay spectra

(DSP1, DSP2) of a CDMA signal transmission between a
CDMA base station (BS) and a CDMA mobile station (MS)
on a plurality of propagation paths (P1, P2) within a
CDMA cell (CL) subdivided into a predetermined number
of sectors (SECT1...SECT6) respectively with two
diversity reception antennas (Ant1, Ant2), including:

a path selection unit (PSU) for determining from said
real power delay spectra (DPS1, DPS2) the delay times
$(d_1'...d_N')$ of a predetermined number of propagation
paths (P1, P2) of said multipath transmission, said
path selection unit (PSU) including:

a peak detection/removal means (PD-RV) for detecting a
predetermined number of peaks (MAX1, MAX2, MAXn) in
said power delay spectrum (DPS) and for removing or
setting to zero at least those samples of said real
power delay spectrum (DPS) corresponding to the
detected peaks;

a noise estimation means (NEST) for averaging the real
power delay spectrum (DPS) having the peak samples
removed or set to zero to determine an effective noise
value;

a path estimation means (PEST) for selecting delay
times $(d_1'...d_N'; d_{max1}...d_{MaxN})$ of the determined
peaks which exceed a threshold ($\overline{DPS^*}$ x THRS) formed
by multiplying the effective noise value with a
threshold factor (THRS);

an adder (ADD) to sum up a first and second real power
delay spectrum (DPS1, DPS2) of the two antennas (Ant1,
Ant2) per sector, wherein the peak detection and

removal means (PD-RV) detects and zeros or removes peaks in said added real power delay spectrum (DPS'); and

a first and second path verification means (PVER1, PVER2) for comparing the multiplied threshold ($\overline{DPS^*}$ x THRS) determined by said path estimation means (PEST) respectively with said first and second real power delay spectrum (DPS1, DPS2) of each antenna at the determined delay values (d_{max1}, d_{max2}, d_{maxN}) wherein only such peaks in the first and second power delay spectrum are detected which are equal or above the multiplied threshold.

25. A means (STU; Fig. 10) according to claim 24, **characterized in that** said path selection means (PSU) further comprises:
a maximum detection means (MAX) for receiving the candidate peaks from the respective path verification means (PVER1, PVER2) from a plurality of search means (S1...SL) each serving one or more sectors (SECT1...SECT6) and for ordering a predetermined number (N) of highest peaks as well as their delay times ($d_1'...d_N'$) output by the path verification means (PVER1, PVER2) of the respective search means (S1...SL) in a descending order and for determining a selection information ($s_1'...s_N'$) for each delay time ($d_1'...d_N'$) indicating to which sector (SECT1...SECT6) the respective delay times ($d_1'...d_N'$) belong.

26. A multipath propagation delay determining means (STU) determining real power delay spectra (DSP1, DSP2) of a CDMA signal transmission between a CDMA base station

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(BS) and a CDMA mobile station (MS) on a plurality of
propagation paths (P1, P2) within a CDMA cell (CL)
subdivided into a predetermined number of sectors
(SECT1...SECT6) respectively with two reception
antennas (Ant1, Ant2) including:

a plurality of search means (S1...SL) for determining
said real power delay spectra (DPS1, DPS2) of the
multipath transmission in each sector;

a path selection unit (PSU) for determining from said
real power delay spectra (DPS1, DPS2) the delay times
$(d_1'...d_N')$ of a predetermined number of strongest
propagation paths (P1, P2) of said multipath
transmission and resepctive selection information
$(s_1'...s_N')$ indicating the active sectors
(SECT1...SECT6) to which said delay times $(d_1'...d_N')$
belong;

a tracking and control means (TRCU) for determining on
the basis of said delay times and said selection
information $(s_1'...s_N')$ the active and non-active
sectors, a sector scanning rule (Fig. 13) to instruct
the selection means (SEL) to apply particular antenna
signals to said search means (S1...SL) at particular
timings in the respective time slots (TSi) of the
radio frames (RFn) and for evaluating the real power
delay spectra (DPS) respectively obtained when
applying the particular antenna signals to the search
means (S1...SL) to determine the location and/or the
moving direction of the mobile station (MS) within the
CDMA cell (CL).

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5   27.   A means (STU; Fig. 6, 13, 15) according to claim 26,
           characterized in that
           said tracking and control unit (TRCU) receives said
           selection information values ($s_1'...s_N'$) and said
           delay times ($d_1'...d_N'$) and selects a predetermined

10   number (P) of delay times ($d_1...d_P$) and corresponding
           selection informations ($s_1...s_P$).

    28.   A means (STU; Fig. 6, 13, 15) according to claim 26 or
           27, *characterized in that*

15   said tracking and control unit (TRCU) determines, on
           the basis of the number of time slots (TSi) in each
           radio frame (RFn), the number of total sectors
           (SECT1...SECT6), the number of search means (S1...SL),
           a predetermined update period (10ms) for active

20   sectors and the number of currently active and non-
           active sectors as indicated by said selection
           information ($s_1'...s_N'$, $s_1...s_P$), a predetermined
           number of coherent and non-coherent calculations of
           the real power delay spectrum (DPS) and the update

25   period for non-active sectors (SECT1...SECT6), said
           sector scanning rule (Fig. 13a, 13b) indicating which
           sector is to be scanned at each respective time slot
           (Tsi) of each radio frame (RFn).

30   29.   A means (STU, Fig. 6, 13, 15) according to one of the
           claims 26 to 28, *characterized in that*
           said tracking and control unit (TRCU) selects a new
           sector scanning rule whenever a status of a scanned
           sector changes from active to non-active or vice vica.

35
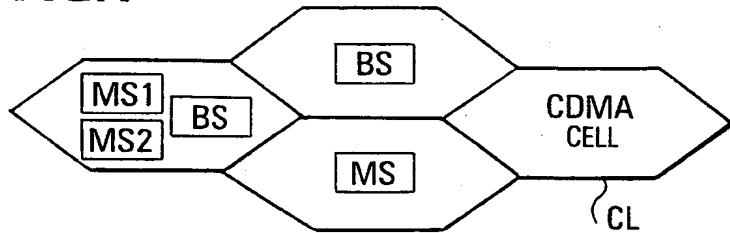
FIG.1

FIG.2a
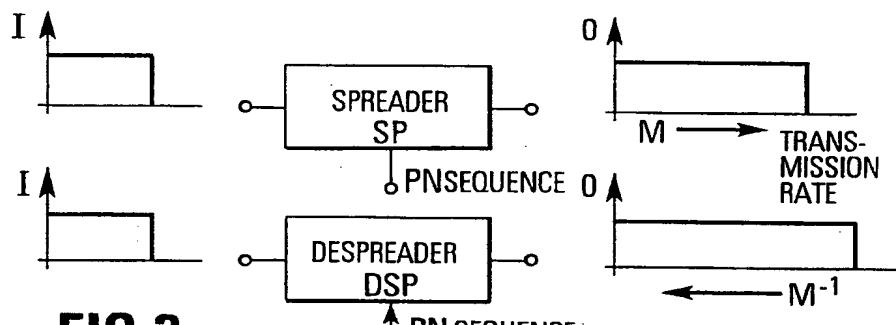
FIG.3
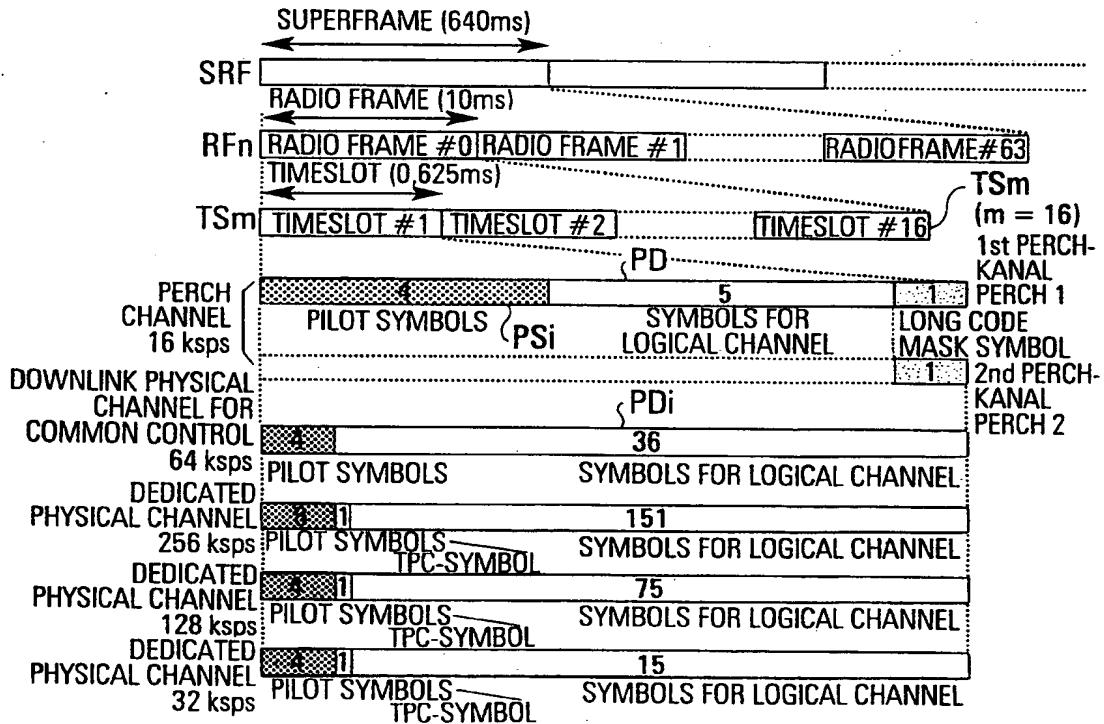
FIG.2b
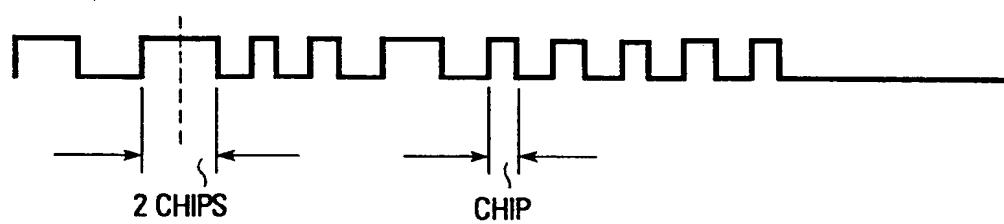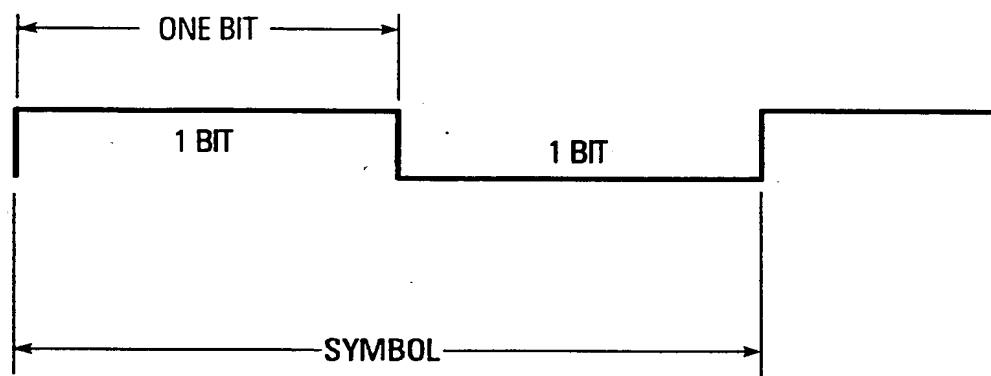
FIG.4
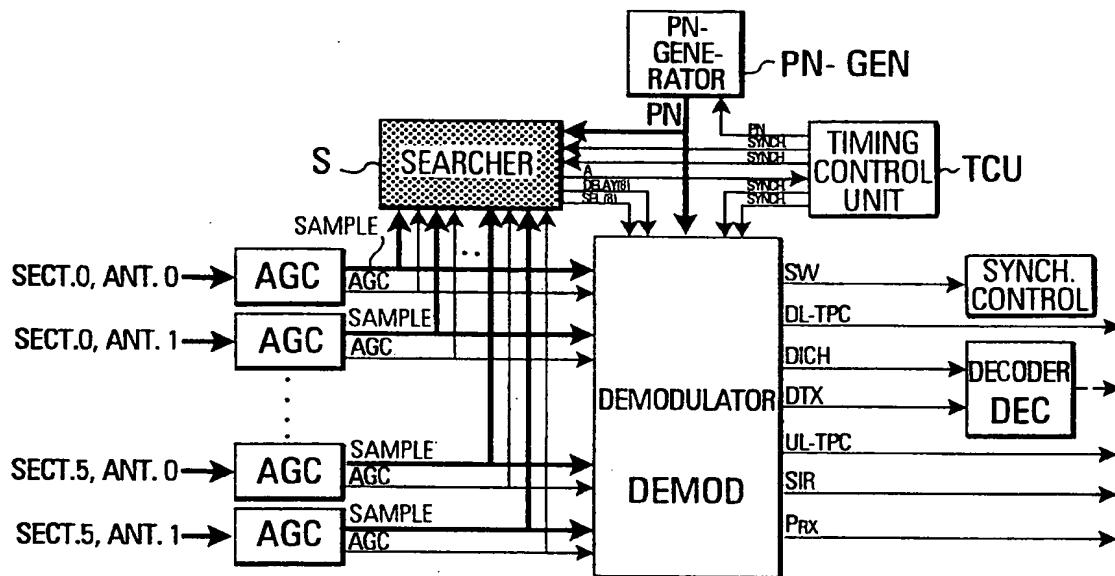
# FIG.5
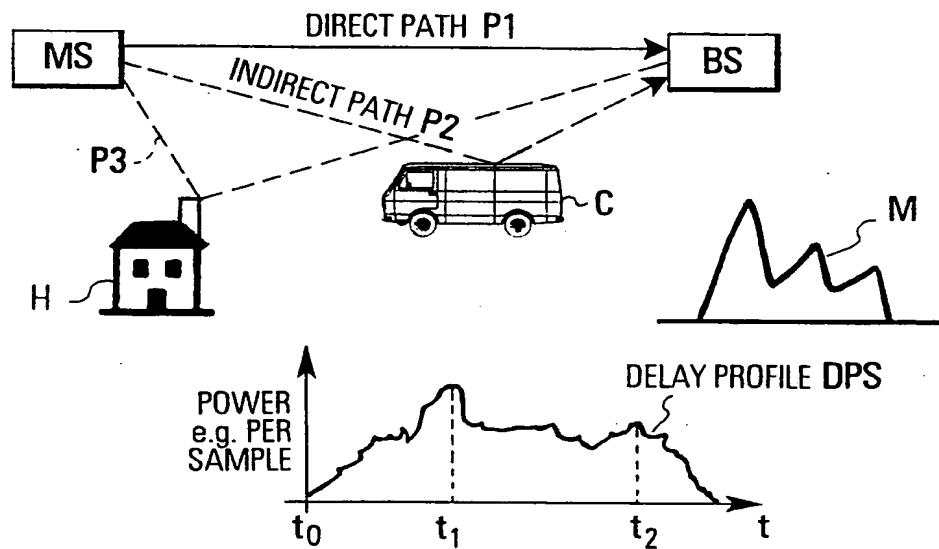
FIG.6
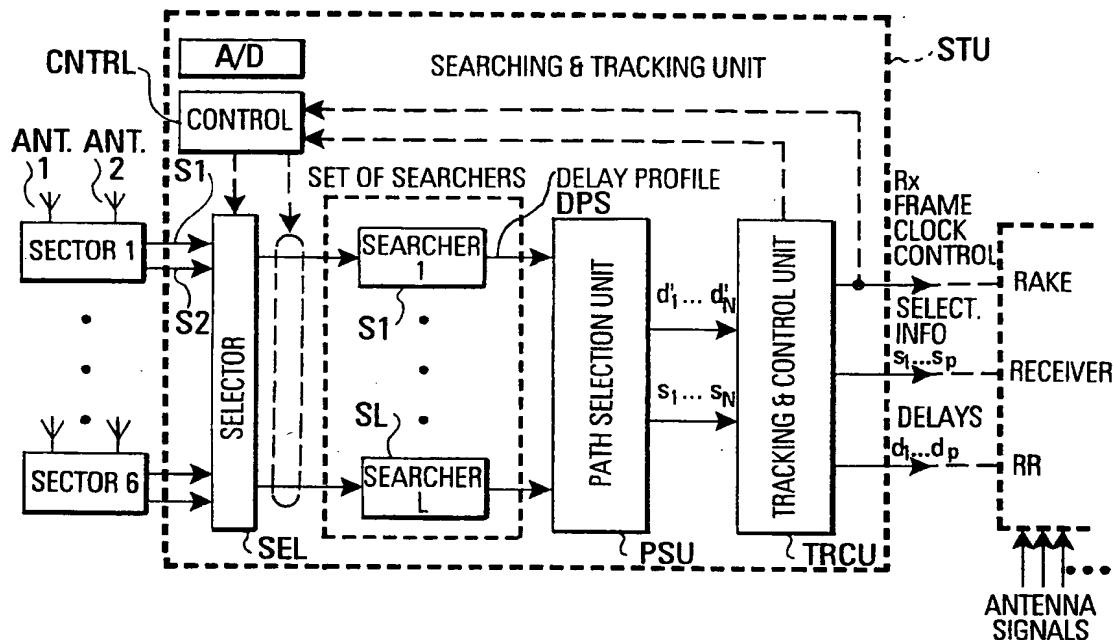
FIG.7
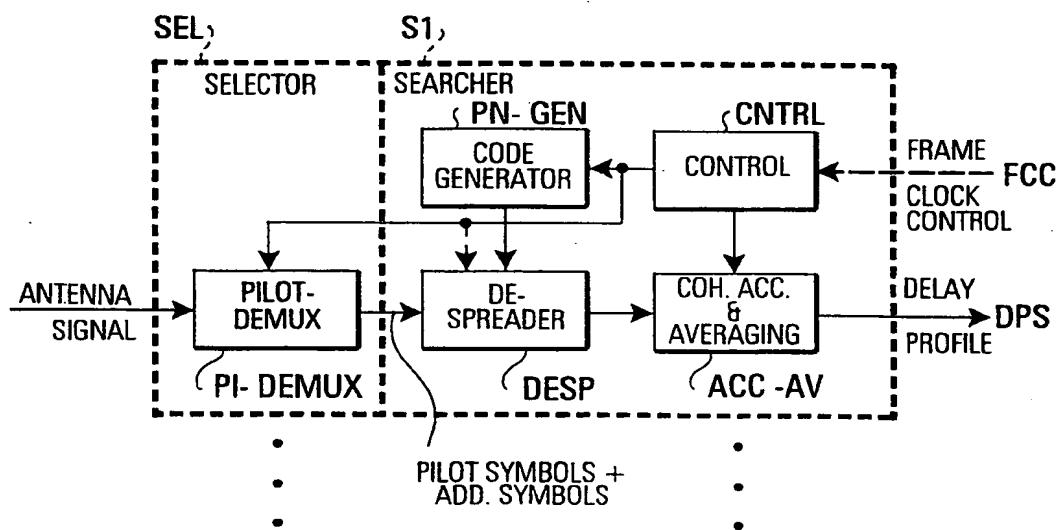
FIG.8
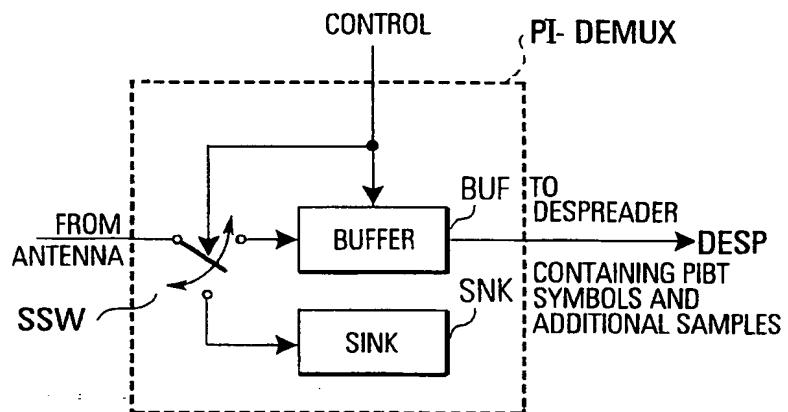
FIG.9
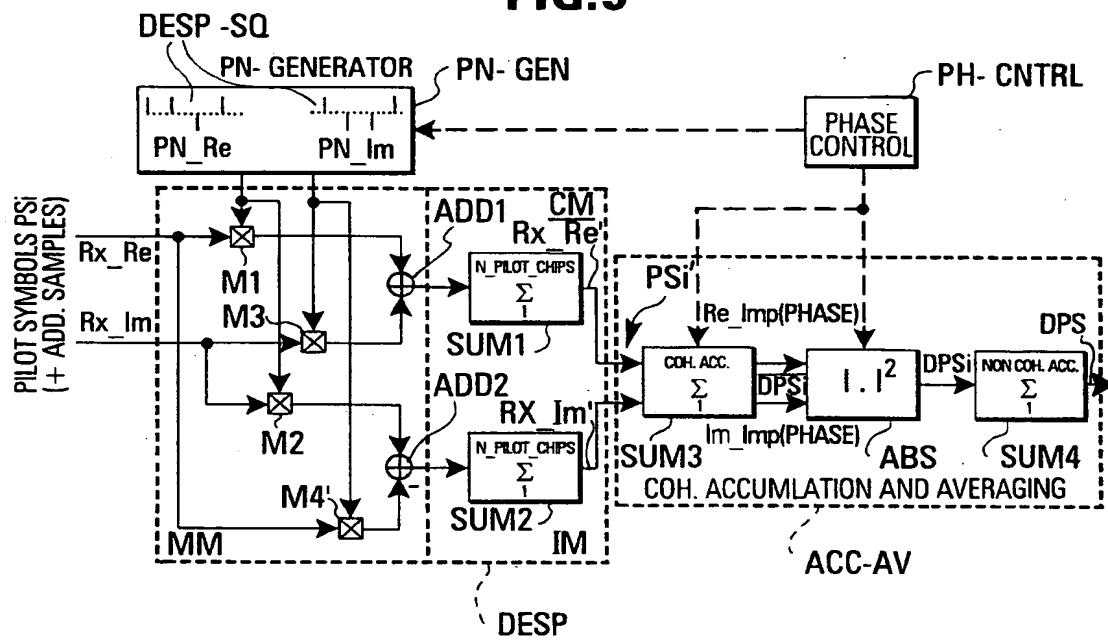
FIG.10
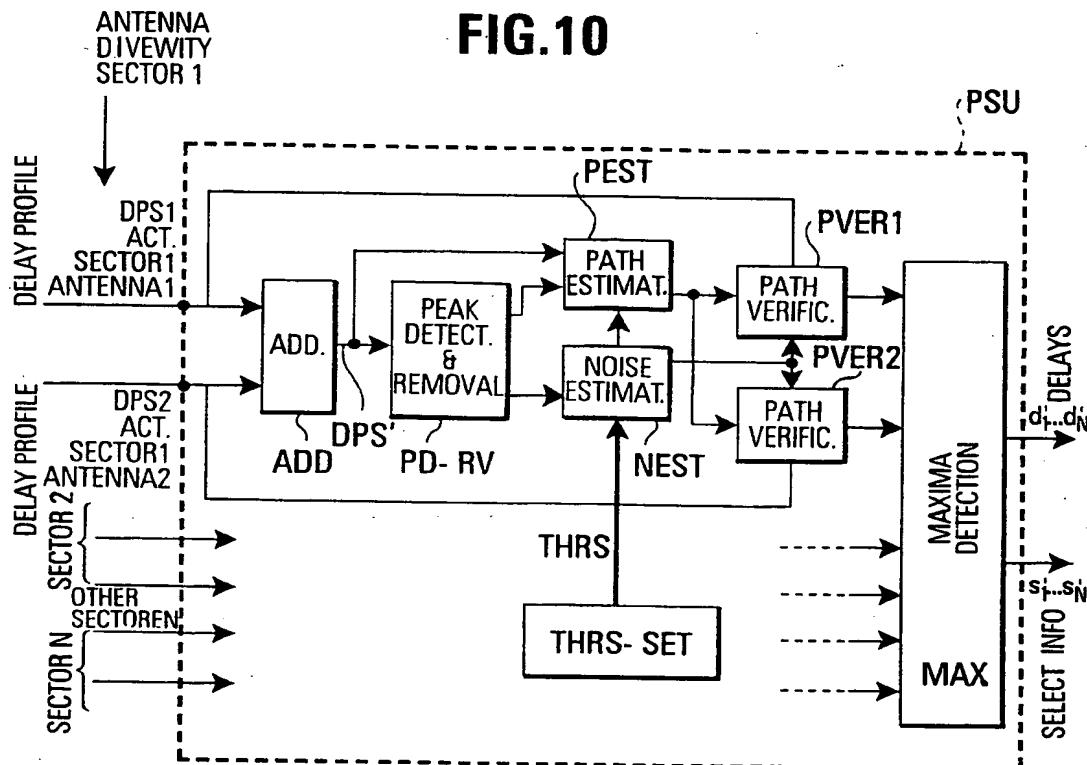
FIG.11
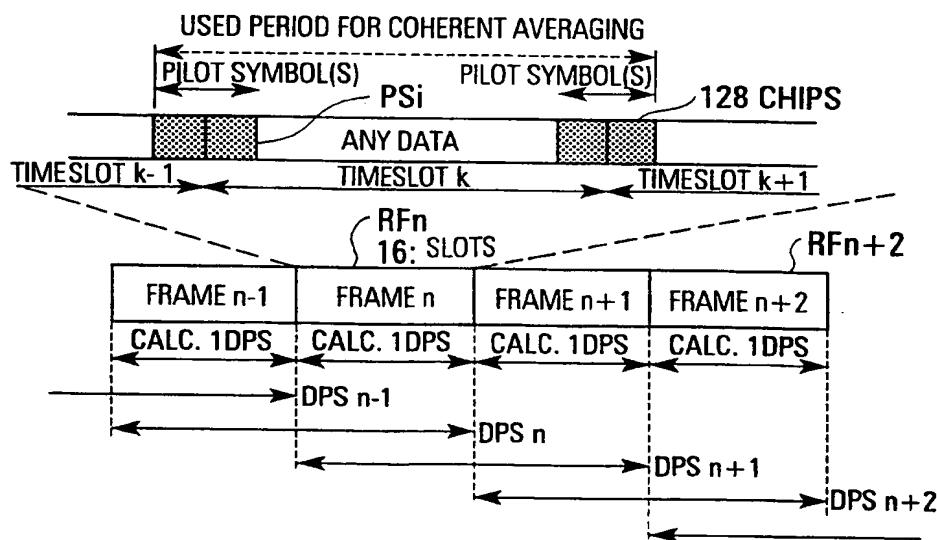
FIG.12
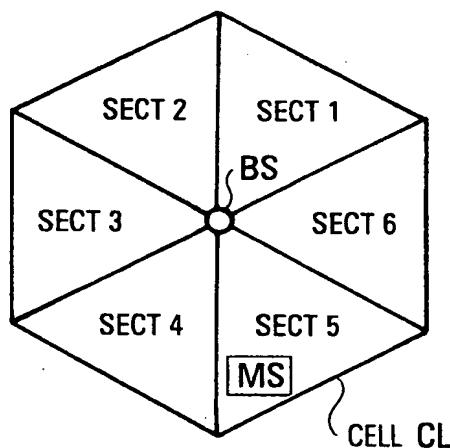
FIG.13

A1$_1$: ACTIVE SECTOR 1, 1st DPS CALCULATION (2 SLOTS)
N1$_1$: NON-ACTIVE SECTOR 1, 1st DPS CALCULATION (2 SLOTS)
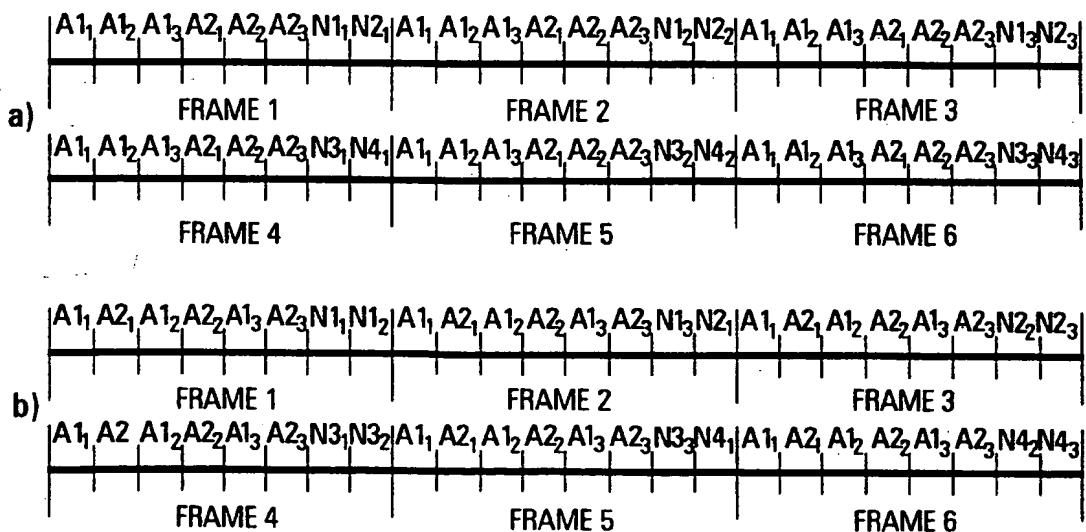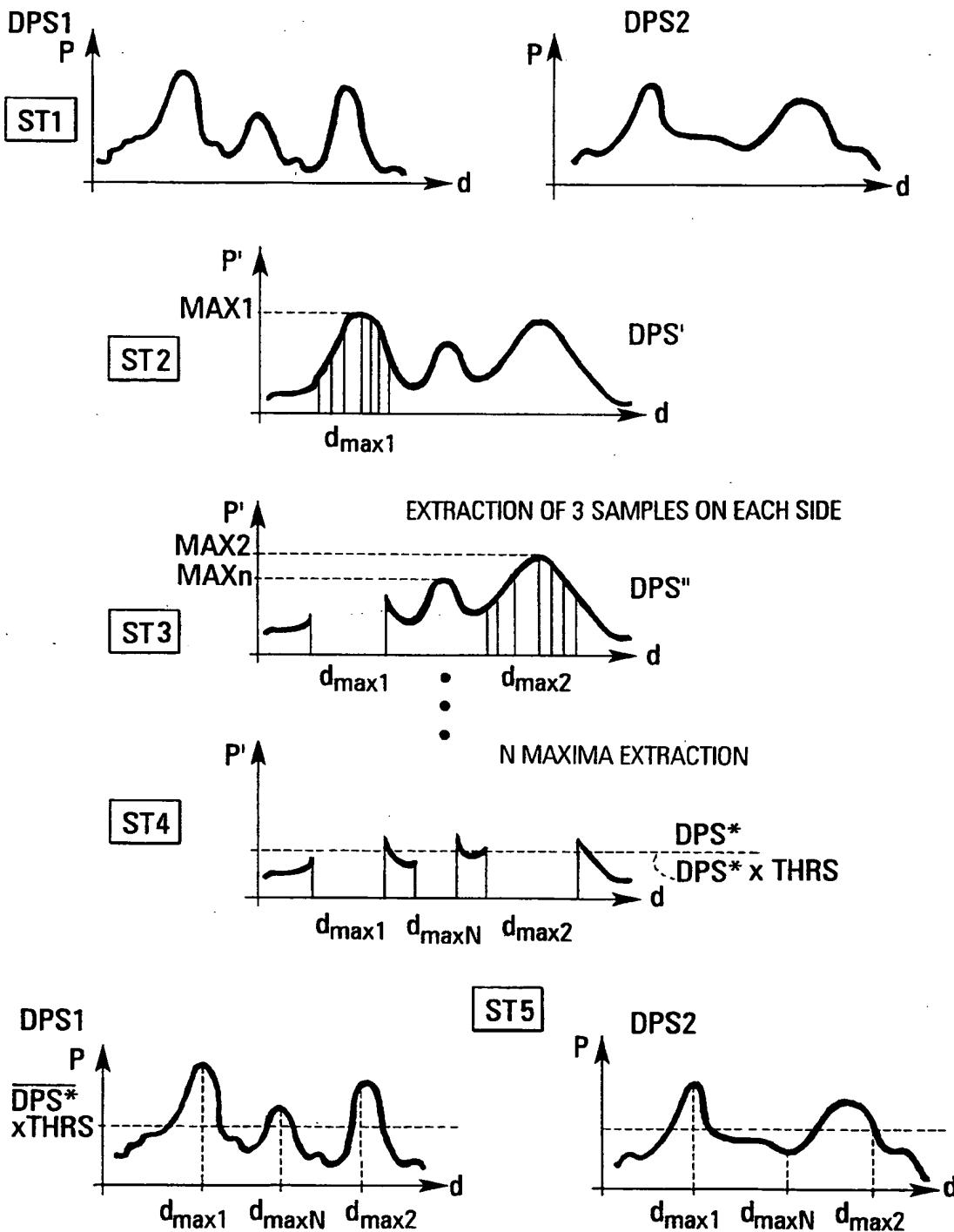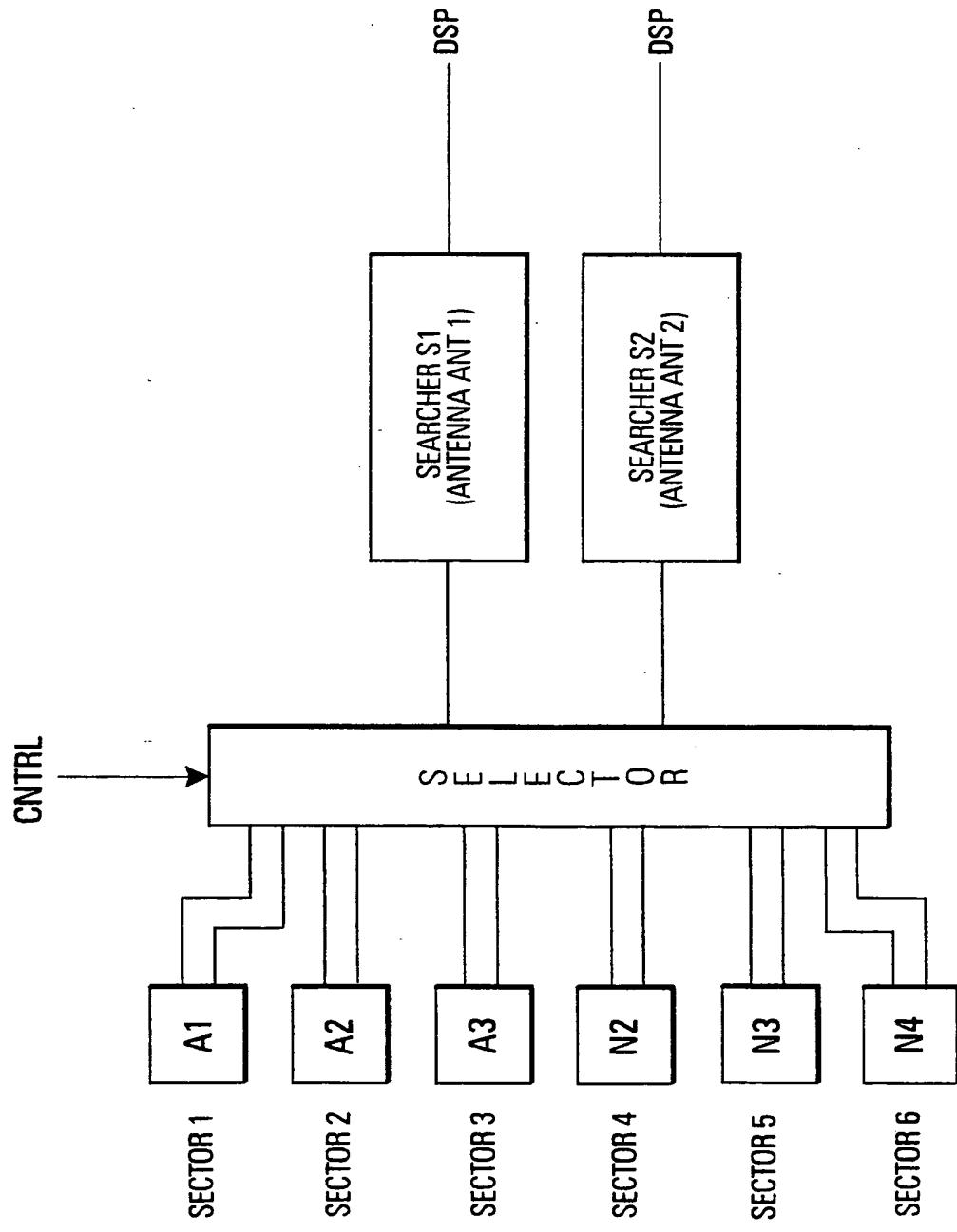
a)

b)

FIG.14

FIG.15

FIG.16

NON-DETECTION AND FALSE ALARM PROBABILITIES (DET. RANGE=2)

Eb/10=5dB, 3 SECTORS, OP= 1, INTERLEAVED

PEAK-TO-NOISE THRESHOLD

PROBABILITY

——	NON-DETECT.: CORRECT PEAKS
– –	NON-DETECT.: ANY PEAKS
–·–	FALSE ALARM

(DR=0)

(DR=1)

(DR=2)

FIG.17

NON-DETECTION AND FALSE ALARM PROBABILITIES (DET. RANGE=2)

Eb/I0.=5dB, 1 SECTOR, OP= 1, INTERLEAVED

PEAK-TO-NOISE THRESHOLD

PROBABILITY

— NON-DETECT.: CORRECT PEAKS
—-— NON-DETECT.: ANY PEAKS
—·—· FALSE ALARM

(DR=0)
(DR=1)
(DR=2)
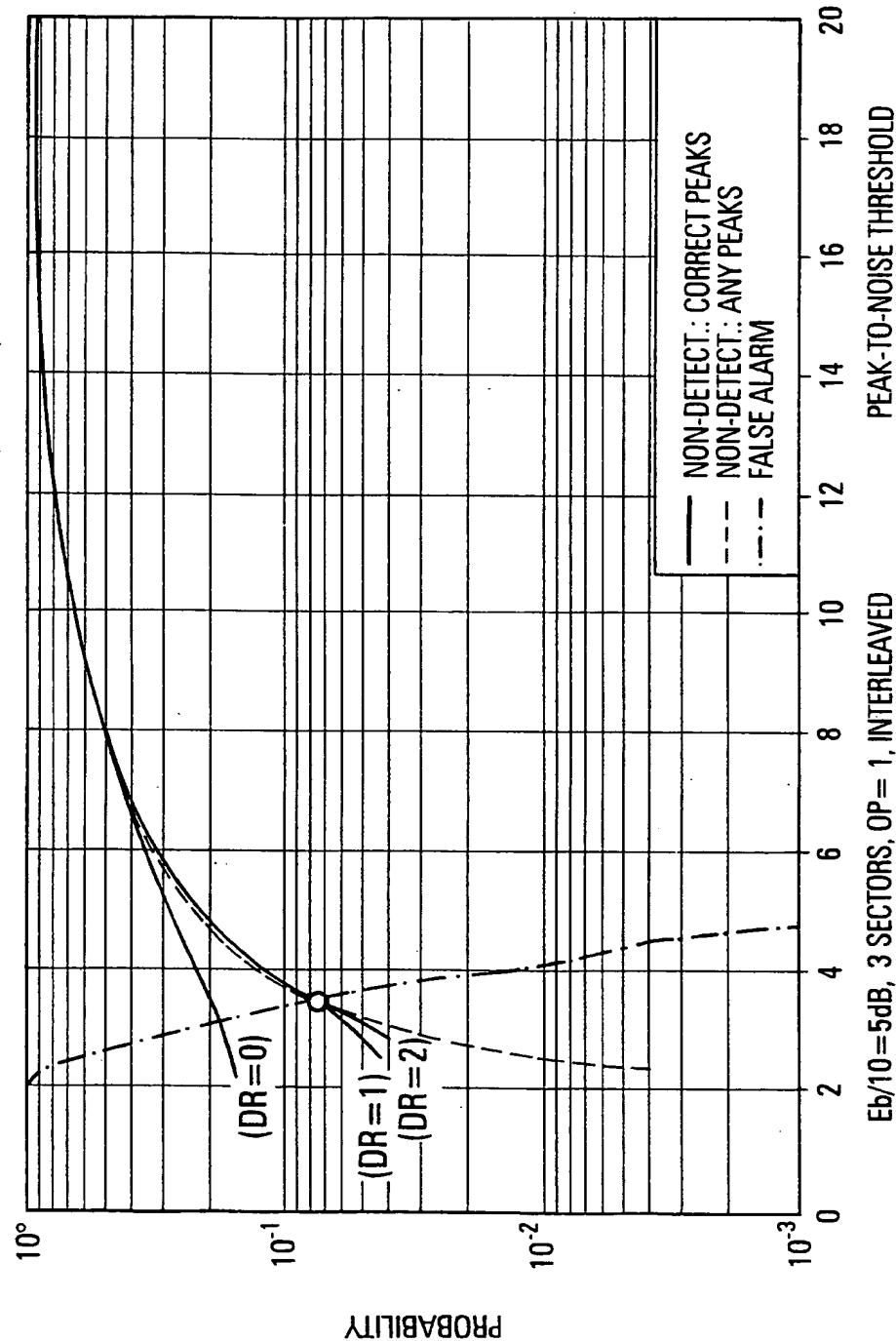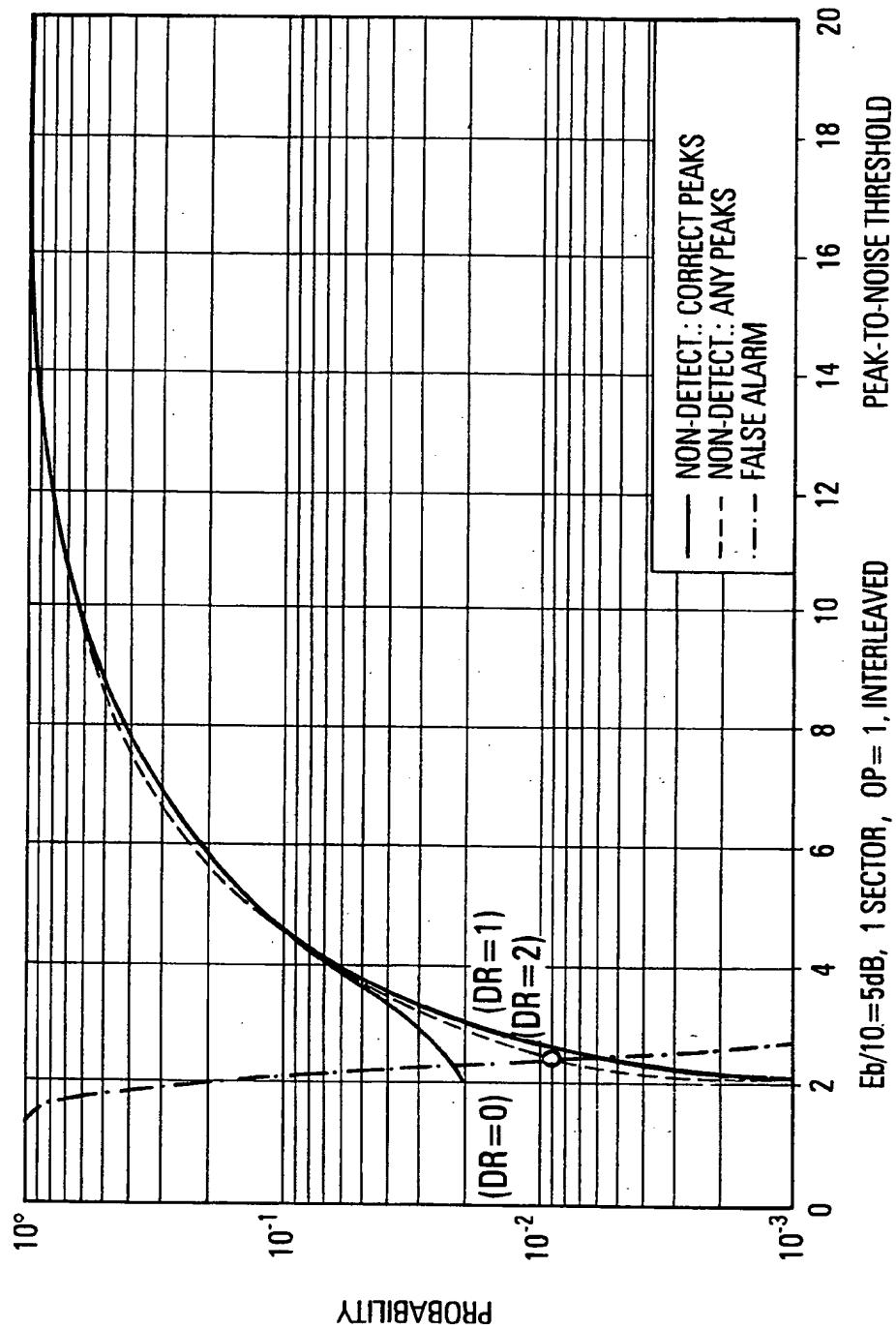
FIG.18

CROSS-OVER PROBABILITIES: NON-DETECTION AND FALSE ALARM, M=64

o 1 SECTOR
✱ 3 SECTORS
— NOT INTERL.
--- INTERLEAVED

Eb/10(dB)

2-PATH RAYLEIGH (50 km/h)
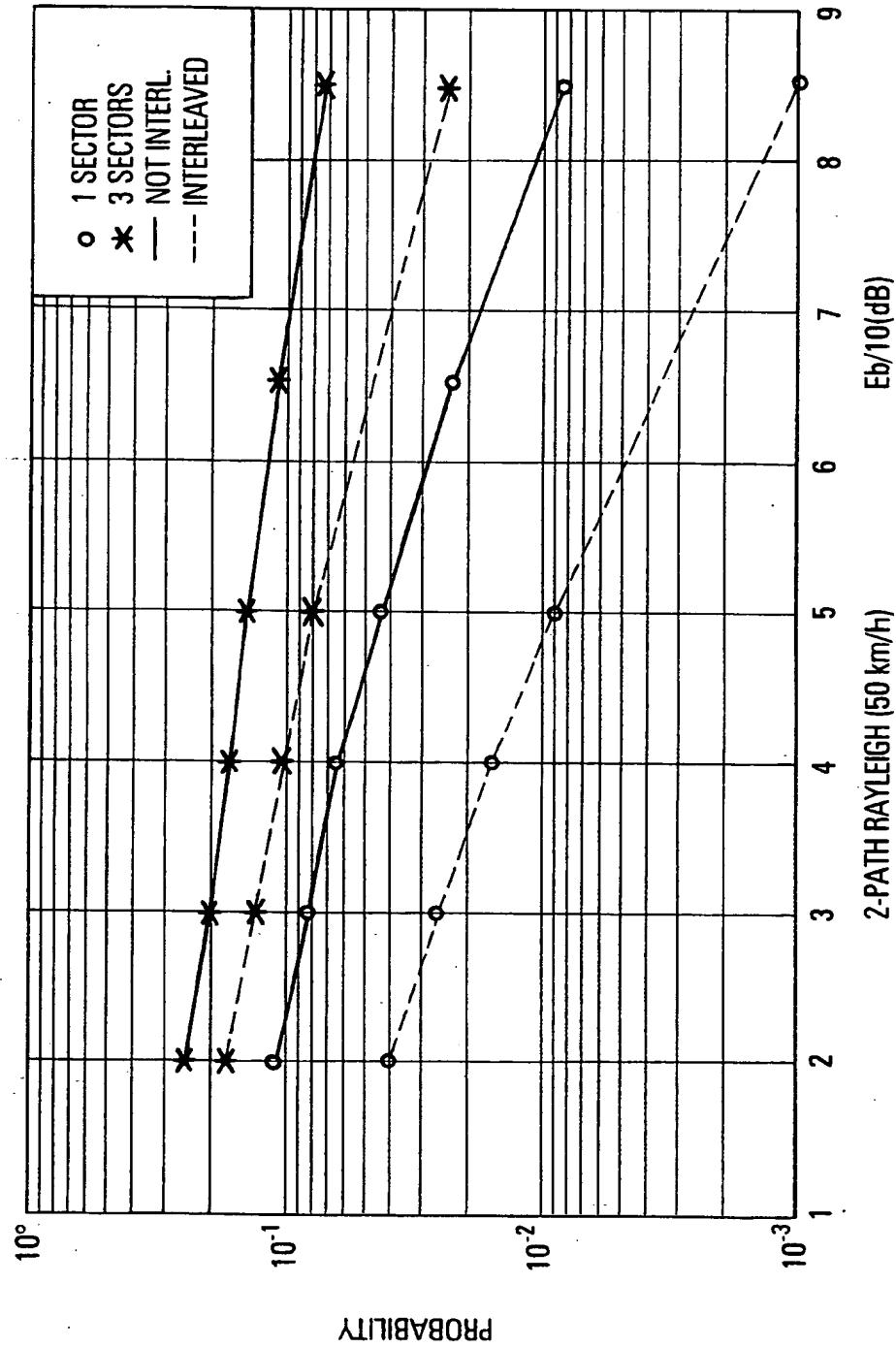
PROBABILITY

FIG.19

PEAK-TO-NOISE LEVEL AT CROSS-OVER PROBABILITIES, M=64
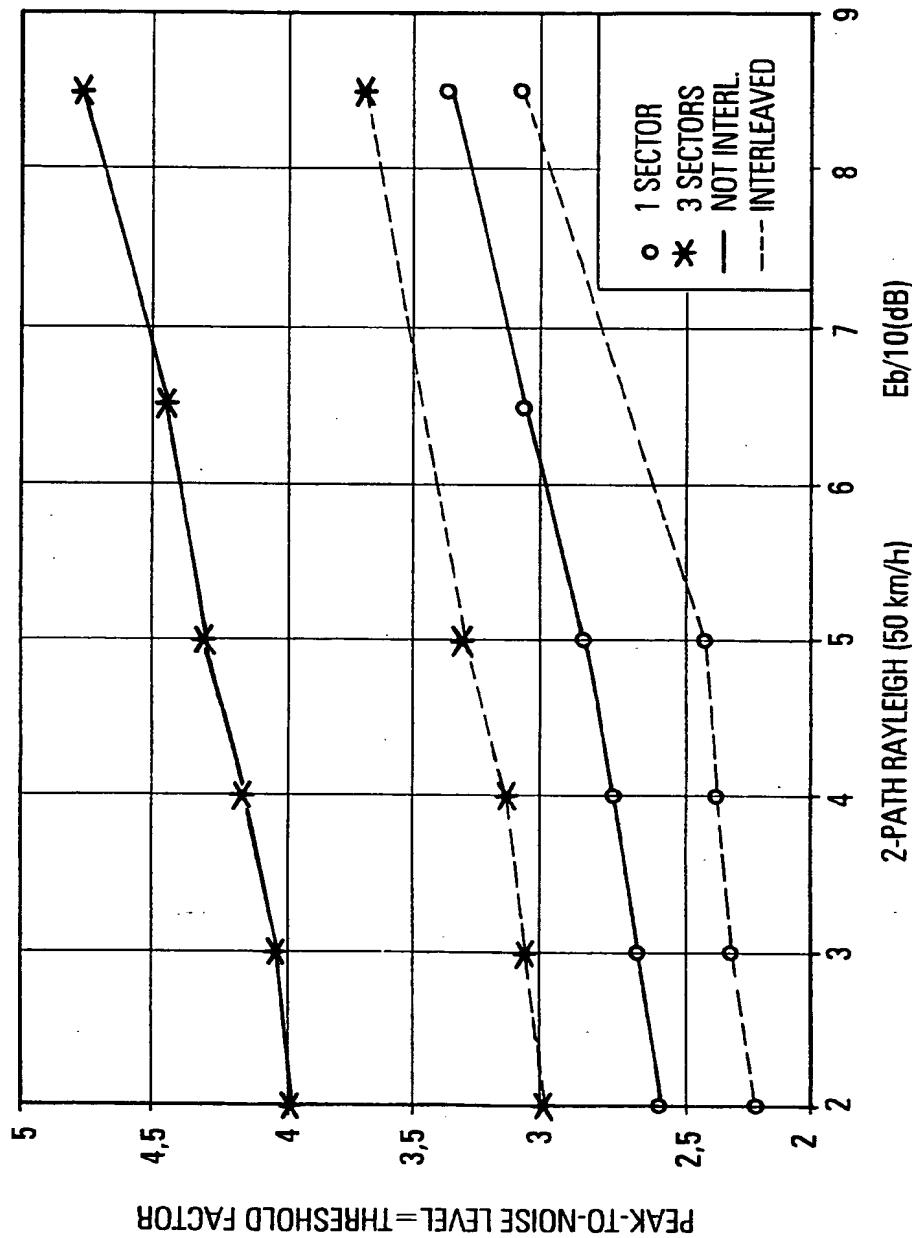
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6   H04B1/707

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6   H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 96 10873 A (QUALCOMM INC) 11 April 1996 (1996-04-11) abstract page 13, line 30 –page 14, line 35 page 16, line 1 – line 6 page 18, line 21 – line 36 page 29, line 4 – line 31 page 30, line 33 –page 31, line 2 page 33, line 18 –page 34, line 35 ——— -/--	1,3,5 2,4,6-8, 11-13, 15,16, 18-29

X	Further documents are listed in the continuation of box C.		X	Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 September 1999	29/09/1999

Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Lustrini, D

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document. with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 776 105 A (NIPPON TELEGRAPH & TELEPHONE) 28 May 1997 (1997-05-28)	1,3,5
A	abstract	2,4,6,7, 11-13, 16-18, 23,24,26
	column 6, line 1 -column 8, line 16 column 9, line 1 -column 10, line 59 column 12, line 1 - line 28 column 15, line 31 -column 16, line 46 column 20, line 52 -column 21, line 56 figures 11,12 ---	
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